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TOTAL SOLAR ECLIPSE, 1936 JUNE 19: REPORT OF THE
EXPEDITION TO KAMISHARI.

F. J. M. Stratton.

An expedition to observe the total solar eclipse of 1936 June 19 in the Hokkaido, Japan, was arranged by the Joint Permanent Eclipse Committee with the aid of grants from the Government Grant Fund of the Royal Society and from the Solar Physics Observatory, Cambridge University. The party from Cambridge consisted of Prof. F. J. M. Stratton, Dr. R. O. Redman, Dr. C. W. Allen and Major R. A. Bagnold, Royal Signals; Dr. A. D. Thackeray, Commonwealth Fund Fellow, joined the expedition from Mt. Wilson Observatory. The Government of India sent Dr. Royds, Director of the Kodaikanal Observatory, to observe the eclipse, and it was arranged that he should join the expedition to Kamishari.

The National Research Council of Japan arranged for a careful survey of the belt of totality, which ran along the north-east coast of the island of Hokkaido, and they issued well in advance of the eclipse a valuable pamphlet giving available meteorological information, details as to accessibility for heavy goods and facilities for such necessities as electric light and power, water supply, and good sites for observation. After careful examination of the report and consultation with the Meteorological Office it was decided to arrange if possible to go to Kamishari, a small village a few miles inland from the coast. The Japanese authorities agreed to our request with every possible courtesy: in fact Professor Matsukuma of the Imperial University of Sendai, who had originally intended to take an expedition to Kamishari, most kindly changed his plans to make room for us and went instead to the neighbouring village of Koshimizu. It is pleasing to report that he was favoured there with a clear sky during totality.

Dr. Fukumi, Secretary of the Japanese National Eclipse Committee,



accompanied the advance party (Major Bagnold, Dr. Royds, Professor Stratton) to Kamishari and made all the necessary arrangements with the Government of Hokkaido, the Prefecture of Abashiri, and the local eclipse committee for the site of the eclipse camp, the accommodation of the observers and the provision of huts, concrete pillars, electric light and power for the camp. All the preliminary arrangements made by him worked out quite successfully, all contract work such as the erection of huts and pillars being completed before the arranged date. Throughout the stay of the party at Kamishari a Government official who could deal with difficulties of language was attached to the party; special mention must be made of the services of Mr. T. Sugawara, who spent several weeks with the party and rendered many helpful services.

The main party of observers arrived at Kamishari six weeks before the date of the eclipse, rather more time than usual being allowed for the work of preparation owing to uncertainty as to the conditions under which the work would have to be carried out. The site suggested for the camp, an open piece of ground at the back of the primary school, well away from the road and protected from dust by a belt of trees, proved attractive and was accepted readily. Owing to the kindness of Professor Nakaya of the Imperial University of Sapporo the workshop of his physical laboratory was made available for any instrumental repairs that might prove necessary, and advantage was taken of this for certain minor repairs. The usual routine of laying out the camp, constructing shelters for the spectrographs, erecting pillars for the cœlostats, cameras and spectrographs was followed; instruments were set up and adjusted and everything was ready four or five days before the eclipse. During the last three days an additional group of observers, including Dr. F. W. Aston, Principal G. H. Marsden of the Scott Christian College, Nagercoil, S. India, Professor Nakaya, Mr. T. Sakurai, and a party from the British Embassy at Tokyo, joined the expedition in time for full rehearsals of the work that each was to carry out at the eclipse. The names of these volunteer helpers will occur in the accounts of the various instruments. Paymaster-Lieutenant J. P. MacIntyre, R.N., counted the seconds during the eclipse.

On the whole, except for the week before the eclipse, the weather had not been too promising. A steady fine spell ended in a very hot day on Sunday, June 14, and a subsequent storm was followed by broken weather up to the day of the eclipse, June 19. On the day itself the morning was variable, but the Sun broke clear of the clouds about half-way through the partial phase and remained in a large clear gap until just before second contact, which was computed to be at $15^{\text{h}} 21^{\text{m}} 58^{\text{s}}$ local mean time. Dr. Royds was enabled nearly to complete the first half of his programme of observation, but during the last five minutes before totality clouds began to gather round the Sun. Second contact was observed through gathering cloud, with the Sun half covered, the clear half being on the opposite limb to second contact; five seconds later the eclipsed Sun was completely covered by clouds, too thick to be penetrated even by the infra-red cameras. Ten minutes after third contact the Sun broke clear again. The three

nearest Japanese parties, including one near the top of Mt. Shari occupied in measuring cosmic radiation, all secured a perfect view of the eclipse.

The programme of proposed observations is given below. The work of Dr. Royds, Dr. Redman and Dr. Thackeray will be described in detail in separate papers and will only be mentioned here: Their programme was as follows:—

(i) *Wave-lengths of the Fraunhofer Lines during the Eclipse*.—Dr. Royds and Principal Marsden.

(ii) *Intensities of Lines of the Chromospheric Spectrum*.—Dr. Redman and Lt. Pender-Cudlip, R.A.

(iii) *Ultra-violet Spectrum of the Chromosphere and Corona*.—Dr. Thackeray.

The other observations detailed below were concerned with the corona and were spoilt by clouds. It may be mentioned here, to avoid repetition, that arrangements were made to prepare all the plates for photometric measurement, a tube sensitometer being used for the direct photographs and calibrated wedge spectra for the spectrograms.

(iv) *Spectrum of the Outer Corona*.—The 20-inch Common reflector, focal length 45 inches, was fed by a 16-inch cœlostast used with a 1-prism spectrograph with two Aldis anastigmat lenses of 12-inch focus working at $f/3$. The spectrum of the outer corona was to be examined, especially the distribution of coronal lines at different heights above the Sun's limb, and the Fraunhofer spectrum. In order to secure as great a range of height as possible the image of the Sun was placed at one end of the slit of the spectrograph, the slit being radial to the Sun at a solar latitude determined in conjunction with the polarisation programme. The end of the slit at which to place the Sun's image was chosen naturally as that towards which the Sun's image was moving owing to the daily change in declination during the weeks preceding the eclipse. The choice made proved unfortunate, as the side of the Sun on which the slit lay was in thick cloud throughout totality. Preliminary sky spectra showed the instrument to be well adjusted and the spectrograph in good focus over a wide range of spectrum. Dr. Allen was responsible for the preliminary adjustments and Professor Nakaya had charge of the instrument for the eclipse.

(v) *Direct Photography of the Corona*.—The principal coronagraph was the 19-foot coronagraph (the tube kindly lent by the Royal Observatory, Greenwich) with a 4-inch lens and an 8-inch Grubb cœlostast (both kindly lent by the Royal Irish Academy). As at the eclipses of 1926, 1932 and 1934 a 4-inch direct-vision prism (kindly lent by the Royal Observatory, Edinburgh) was placed in front of the camera lens for the flash spectrum at second and third contacts. The usual spectrum of crescents was obtained for the stronger lines at second contact, but it was badly spoilt by clouds. By the time the prism had been removed and the first direct exposure on the corona was started, the corona was lost to view behind the clouds. The instrument was worked by Major Bagnold with the assistance of Lt. F. Piggott, the Queen's Regiment.

Two infra-red coronagraphs working through infra-red filters (Wratten

88) were also employed. One camera was used with a 6-inch Henry lens of 92 inches focal length, giving an image of reasonable size for comparison with photographs secured in the photographic region. This camera was fed from a 12-inch cœlostast and worked during the eclipse by Mr. Bromley of the Tokyo Embassy staff. The second infra-red camera was mounted equatorially. It had a Dallmeyer lens of 3.8 inches aperture working at $f/5$. With this it was hoped to secure faint extensions of the outer corona. Mr. Sugawara was in charge of this instrument.

An ultra-violet coronagraph was brought by Dr. Thackeray from the Mt. Wilson Observatory. The lens of $3\frac{1}{4}$ inches aperture and 5 feet focal length (kindly lent by Dr. A. S. King) was made of quartz and was silvered on one face so as to transmit light of effective wave-length 3220 Å. It was fed from the aluminized 16-inch cœlostast used for the double-tube camera. Major Cardew was in charge of the instrument at the eclipse, Dr. Thackeray having made the preliminary adjustments.

Owing to clouds no photographs of value were obtained with any of the coronagraphs.

(vi) *Polarisation of the Corona*.—A double-tube camera with two 3-inch Cooke lenses of 51 inches focal length was used with a 2-inch Nicol prism (kindly lent by Professor Newall) in front of one lens and a suitable diaphragm in front of the second lens. Four exposures with the axis of the prism set to examine radial polarisation at solar latitudes 90° , 0° , $\pm 30^\circ$ formed the programme. Only the first plate could be secured and that only for a third of the exposure intended, which was 15 seconds. The corona shows strongly over one-half of the Sun's limb, but light scattering by haze and clouds is obviously present and prevents accurate measurement of the variation of the amount of polarisation at different heights above the limb. Comparison at the pole and the equator of the two plates with and without the Nicol gives clear evidence of polarisation at the one pole which is not covered by clouds. The figure given by the plates is 10 per cent., but owing to the conditions of observation this figure is not put forward for final acceptance. Dr. C. W. Allen had charge of this instrument.

(vii) *Sky-polarisation*.—An attempt to examine the polarisation of the sky-light in the immediate neighbourhood of the eclipsed Sun was made by photographing the Sun and surrounding sky through a 1-inch Nicol prism and a Savart plate (kindly lent by the Cavendish Laboratory and Professor Newall respectively). It was hoped to repeat an observation of Professor Newall's made at the eclipse of 1905 (*M.N.R.A.S.*, 66, 477). When the instrument is set to give maximum strength to the sky interference bands, these bands will be in phase with the coronal bands along the radius parallel to the direction of polarisation of the sky-light and out of phase with the coronal bands along a radius at right angle. Along this latter radius the region of change over from one set of bands to the other (the white-centred bands and the black-centred bands) will give an indication of the point at which the sky-light becomes of importance relative to the coronal light, a point of some interest in connection with the presence of Fraunhofer lines in the spectrum of the outer corona. Owing to the

varying and broken background, due to clouds drifting past the Sun at second contact, it proved impossible to see the bands due to the sky-polarisation on the ground glass of the camera; as earlier observers had suggested that the plane of polarisation would be either vertical or horizontal it had been decided beforehand to set the axis of the prism along the vertical line through the Sun if observation on the ground glass should prove impracticable, and this was done for the first photograph. On the plate there is no more than a suspicion of bands to be observed, and as their presence cannot be confirmed by the microphotometer no statement as to the result can properly be made. Professor Stratton had charge of this instrument.

At the same time, with a battery of four small Nicol prisms with Savart plates, Dr. Aston was to examine the direction of sky-polarisation near the Sun with a view to detecting any changes during the eclipse accompanying changes in the direction from which the scattered sky-light entered from outside the shadow. Within the first 10 seconds after second contact, Dr. Aston's observations of the position angle at which the interference bands vanished showed that the direction of polarisation of the sky-light was either nearly vertical or nearly horizontal, but clouds prevented the observations necessary to complete the programme.

(viii) *Shadow Bands*.—A sheet was laid out on the ground for the observation of shadow bands by Mr. T. Sakurai. Bands appeared 47 seconds before second contact and were visible for 43 seconds. The bands were about 2 cm. wide with a separation of about 3 cm. The wind was S.W. and the shadow moved from S.E. to N.W. at the rate of 1 metre per second.

It remains to thank various bodies and individuals for assistance to the expedition. A grant from the Government Grant Fund made the expedition possible. Messrs. Alfred Holt & Co. most generously carried the eclipse baggage from England to Japan and back free of charge. The Japanese National Research Council paid for the transport of the baggage by rail from Kamishari to the port of Otaru. The Government of Hokkaido and such of its officials as came into contact with the expedition gave much friendly help and generous assistance. Special mention must here be made of Mr. S. Motomiya, Headmaster of the Kamishari Primary School. Recognition must also be given to the very friendly interest in the expedition shown by people of all classes in Japan, stimulated by a keenly interested Press.

THE CONSTRUCTION AND PERFORMANCE OF A SPECTROGRAPH FOR STUDYING THE SOLAR CHROMOSPHERE.

R. O. Redman.

In our search for a better understanding of the structure of the solar chromosphere it has been found that spectrograms of the greatest value are to be obtained only during a few critical moments at the beginning or end of the total phase of a solar eclipse. One of the chief aims of the observations is to study changes of spectrum line intensity with varying height in the chromosphere. Hitherto this has been done mainly by the aid of slitless spectrographs which produce monochromatic images of the disappearing crescent of the Sun in the light of the numerous lines of the flash spectrum. A continuous record of the changes from Fraunhofer's bright line spectrum is naturally desirable and this is given by Campbell's well-known moving plate spectrograph, which has been employed at many eclipses. However, this instrument utilizes light from merely a very short length of the crescent, and one can only study heights by the variation with time of the light coming from this portion of the image, as it is progressively hidden by the Moon's disc. There is much to be said for photographing the whole image of the crescent, since heights may then be compared by measuring simultaneously at different distances from the cusps, but if this method is adopted, it becomes impracticable to obtain a continuous record and successive separate exposures have to be made, as in the "jumping film" instrument used by Menzel and others. A third way is to employ a slit spectrograph, where the greater and constant resolving power is of advantage; then the intensity-height relation must be studied by following the course of line variations along the slit, which is set tangential to the Sun's image at the point of second or third contact. Here again, if all spectrum lines are to be photographed, it is not practicable to obtain an unbroken record; spectrograms have to be taken at discrete intervals, with an arrangement whereby as little time as possible is lost in moving the plate and shutter between exposures. A slit spectrograph designed to work in this way was used by the British expedition in Japan at the eclipse of 1936 June 19, and although the observations were partially spoilt by clouds, photographs were obtained which have proved to be of definite value.

The optical parts of the spectrograph, two 60° flint-glass prisms of 3 inches aperture, and two 4-inch Cooke photovisual lenses of 6 feet focal length, were selected after tests had been made with what material was available at the Solar Physics Observatory. The slit, a standard Hilger model of effective working length 18 mm., was purchased specially for this work. The instrument gives excellent definition, but since the lenses are not special spectrograph objectives, the field is rather strongly curved and

it is necessary to use films instead of plates. With a suitably curved holder it was possible to photograph simultaneously the whole of the visible spectrum from above $H\alpha$ in the red down to below K in the violet, the focus being good throughout. The scale of the spectrum was 6.5 Å./mm. at $H\gamma$, the length from $H\alpha$ to K being about 23.8 cm. The slit width used was 0.04 mm. The films were Ilford Panchromatic, double coated.

The collimator and camera tubes were built from brass strips and aluminium sheeting, and were bolted down to a ribbed aluminium-silicon casting which formed the base of the instrument. The general design is such as to facilitate dismantling for transport. Most of the construction was done in the Observatory workshop, except that of the repeating camera back, which was made by the Williamson Manufacturing Company. The framework of the back is of aluminium and aluminium alloy, and the film holder is moved by the aid of a Maltese cross device acting in conjunction with a double rack and pinion, the idea being essentially one suggested by Mr. C. R. Davidson. The holder is supported by rollers working in smooth guides, an arrangement which has proved entirely adequate for the purpose. The ebonite slide is held fixed at the top by a catch, so that while the holder moves downwards between exposures, the film is uncovered as it is required. The motion has to be reversed and the slide automatically pushed in again before the holder is removed from the back. Two holders were supplied, each with space for twelve exposures. So that the emulsion shall lie in the focal plane, whose curvature had been accurately measured in preliminary work at Cambridge, the film is held between formers which consist of parallel thin aluminium strips lying edgewise to the light beam. These have the additional use that they prevent light from one exposure leaking on to part of the film reserved for another. On the shaft which carries the control handle is a disc with electric contacts, through which a shutter placed in front of the spectrograph slit was operated. The same contacts also worked a chronograph pen, so that it was possible for one observer to move the film, operate the shutter, and simultaneously record everything on the chronograph tape, simply by turning the handle steadily. Tests made before the instruments were shipped to Japan showed that the mechanism worked well and that there was so little vibration that no effect whatever could be detected on the optical definition, a satisfactory standard of performance which was maintained at the eclipse.

The shutter consisted of a thin metal blade worked by a solenoid operating against a light spring. It gave good service, but tests with the chronograph showed it to have a lag of about 0.12 second. It would be desirable, if ever the apparatus is used at another eclipse, to modify this arrangement so as to obtain greater efficiency, particularly if it were desired to make the exposures rather more frequently than one per second. The chronograph, a tape instrument originally designed for transit circle work at the Cambridge Observatory, proved a great asset. The exact time and length of each exposure could be found by comparison with one-second signals from a chronometer of known error, and a subsidiary, but not negligible, advantage was that in rehearsals the observer responsible for rotating the camera

handle had a constant check on the efficiency with which he was performing the task.

The spectrograph was fed from a concave mirror, which in turn received light from the 21-inch McClean siderostat, kindly loaned by Sir Francis McClean. The concave mirror, of aperture 30 cm. and focal length 5.5 metres (solar image diameter 4.8 cm.), was specially made for this eclipse by Mr. C. R. Burch, whose kindness is gratefully acknowledged. The spectrograph was placed on two concrete pillars so that the collimator lay just alongside the siderostat mirror, the concave mirror being used as little off axis as possible, while the second observer could then conveniently control the focussing of the image, the slow motions, and a hand shutter on the slit.

The only serious trouble experienced during the preparations at the eclipse camp arose from temperature variations. The climate of northern Hokkaido during May and June proved very changeable, midday maximum temperature rising 28° C. in the course of one particular week. In consequence, the definition given by the spectrograph, which was sheltered only by a temporary hut, partly wood, partly canvas, at times became hopelessly bad, and was never quite so perfect as in preliminary work at Cambridge. By dint of careful nursing the definition obtained at the eclipse was good, but the same or a rather better standard would have been attained with far less trouble and far more certainty if the instrument had been provided with a thermostat, which would have been practicable, as electric power was available on the site.

The programme of observation had as its principal aim the production of spectrograms suitable for accurate measurement of line intensity distribution with height in the chromosphere. For this, eight exposures were to be made at second contact and again at third contact, the duration of each being about 0.6 second, while the interval allowed for the shutter to work and the film to be moved was 0.4 second. The spectrograph slit was to be tangential to the Sun's limb. The first series of exposures was to start 2 seconds before the computed time of second contact, the second series 6 seconds before third contact. The original programme also included four calibration exposures on each film, two to give the characteristic curve of the photographic emulsion, two to provide a "black-body calibration"—in other words, a means of comparing intensities at widely separated wavelengths. The first two relied on the familiar wedge method; the others were normal solar spectra from the centre of the Sun's disc, photographed on film 1 as late as possible before second contact and on film 2 as early as possible after third contact. The two films were to be brush developed together in M.Q.

As is known, the programme was severely curtailed by clouds, which were covering the Sun rapidly just at second contact. However, of the eight exposures on the first film, six can be seen, the last two showing a rapid diminution of brightness. For none of the six was the disc properly clear, and, indeed, it is surprising that the last two exposures are visible, since by the time they were being made the Sun's image could not be seen

on the slit. The second film was not exposed at all, owing to hopeless sky conditions. This is doubly unfortunate, as by some accident, the exact cause of which is still unknown, three of the four calibration exposures were fogged. (It is certain that this was not due to a leaky camera back, as focus films taken just before the eclipse and handled without any particular precaution were quite clear.) As it happens, the fogging, which does not touch the flash spectrum, has been of smaller importance than was originally feared, for the sky conditions were such that the two black-body calibrations could not in any case have been profitably used. The unaffected wedge exposure has proved sufficient to act as a basis for the limited amount of spectrophotometry which the exposures justify. The presence of heavily scattering clouds, changing rapidly during and between each exposure, renders it unlikely that any information of value can be obtained with regard to height distribution in the chromosphere; but, on the other hand, it is possible to ascertain how useful this observational method could be under good conditions, while a very fundamental point, as to how accurately sharp chromospheric emission lines can be measured on in-focus slit spectrograms, can also be investigated. Dr. Thackeray has kindly undertaken the measurement and reduction of the exposures, and his work is described in the next paper.

Details with regard to exposure times are given in the following table. The position of the camp was longitude $144^{\circ} 35' 43''$ E., latitude $43^{\circ} 50' 4''$ N.; and the time of second contact, computed from the best data available before the day of the eclipse, was $6^{\text{h}} 21^{\text{m}} 58^{\text{s}}.1$ U.T.

	Time of Mid-exposure			Length of Exposure	Remarks
	h	m	s		
1	6	21	55.5	0.53	rather faint very faint
2			56.5	0.52	
3			57.4	0.58	
4			58.4	0.54	
5			59.3	0.52	
6	22	00.2		0.57	

The times of mid-exposure are corrected for shutter lag and should not be in error by much more than $0^{\text{s}}.1$. The length of exposure should be correct to a few hundredths of a second.

Each of the first four exposures shows a Fraunhofer spectrum broken up into strips which diminish in intensity from exposure to exposure and presumably correspond to various Baily's beads whose images happened to lie over the slit. At the edge of each strip are numerous emission lines, the spectrum becoming very complicated where these overlap the Fraunhofer lines. Exposure 5 shows only faint strips of continuous spectrum, and all traces of the latter must have vanished very soon after this exposure started, viz. at $6^{\text{h}} 21^{\text{m}} 59^{\text{s}}.1$, which is just one second later than the computed time of second contact. Fraunhofer lines are clearly seen in exposure 4, but have not been detected in No. 5, where there is so little continuous spectrum that they would be difficult to see, even if present. The emission

lines of hydrogen and ionized calcium have strong reversals, H and K showing also signs of Doppler motion, probably due to a neighbouring prominence.

As already indicated the instrument worked well, although there are points of detail at which improvement could be made. It is the writer's opinion that plates would give better results than films; they are much easier to handle, are less liable to scratches and other accidental markings, and give more accurate measurements in both micrometer and microphotometer. The camera back worked so smoothly with film that it seems unlikely that the extra weight of a glass plate would adversely affect the performance. With this particular spectrograph, however, the use of plates would necessitate alteration in collimator and camera objectives. If desired, the exposures could without trouble be made more rapidly.

Acknowledgment must be made to the Government Grant Fund of the Royal Society, which met the greater part of the expense of constructing the instrument.

WAVE-LENGTHS AND INTENSITIES IN THE FLASH SPECTRUM.

A. D. Thackeray, Ph.D.

Two instruments were planned to photograph the flash spectrum at the Solar Physics Observatory eclipse camp at Kamishari, Hokkaido, on 1936 June 19. The first, a repeating film two-prism spectrograph, is described above. The second, the Hills four-prism quartz spectrograph, was intended for a search for coronal lines in the extreme ultra-violet, but clouds prevented the recording of any lines but high chromospheric H and K in an exposure of 108 seconds beginning 7 seconds after second contact. An exposure of 2 seconds beginning at the word "Go" was also given for the flash spectrum, and in spite of the fact that rapidly gathering clouds prevented anything being seen on the slit at the time, all the brighter lines, including the Balmer series from $H\delta$ to H 26, are visible (Plate 6 (*e*)); the last line in the ultra-violet that can be detected is $Fe^+ 3227.74$. Ilford Process films were used in a plate-holder with curved back giving perfect focus, as shown by a Hartmann test on the morning of the eclipse at 3100 and 4000 Å. The slit-width was set by Professor Newall's diffractive method, the second diffraction image falling at the edge of the collimator lens ($m=2$). The film has only been used for a photometric measurement of the Balmer decrement, and this, incorporated with measures of $H\alpha$ to $H\delta$ from the moving film spectrograph, are given in a later section. It is interesting to note that the Hills spectrograph had paid a previous visit to Hokkaido for the (cloudy) eclipse of 1896. The 1936 eclipse is the first

occasion on which the instrument has been used with the two components (right-handed and left-handed quartz) of the four prisms in optical contact. The prisms have been refigured since the Sumatra eclipse* of 1926 January.

The results in this paper are based almost entirely on a study of Dr. Redman's excellent series of photographs of the Fraunhofer spectrum of the extreme limb merging into the flash spectrum (Plates 4 and 5). The original problem of variation of the chromospheric lines with height has not been followed up extensively owing to irregular scattering and absorption by clouds producing unknown errors. It is tantalising to see how the emission lines fade out together with the photospheric light from the first exposure (4 seconds before totality) onwards; on exposure V, which shows the last faint strip of continuous spectrum, only about 120 bright lines could be detected (with difficulty). However, the transition from an absorption spectrum to an emission spectrum is excellently shown by the earlier exposures, and it is this problem which has been the main object of study. Exposure IV, the last to show a recognisable absorption spectrum, is a remarkable photograph; the portion of the Sun still visible corresponds to $\cos \theta = 0.99937$ at least (*i.e.* about half a second of arc within the limb), and it is the writer's opinion that this represents the purest slit spectrogram of this portion of the Sun ever obtained in spite of the cloudy conditions. The excellent definition attained is indicated by (a) the appearance of an emission line at 3969.40 Å. between *H* and *H ϵ* , never before recorded in a flash spectrum; Evershed † has found a reversal at the limb at this wavelength; the line can be identified with *Fe*⁺ *a*⁴*P* - *z*⁶*D*^o (I.Q. $1\frac{1}{2} - 2\frac{1}{2}$ and $2\frac{1}{2} - 3\frac{1}{2}$); (b) *He* 4471 reveals its doublet structure on microphotometer tracings in spite of the great disparity in strength of the two components.

Before presenting the results it is appropriate to discuss the applicability of the instrument to the problem of chromospheric intensities at different heights. The continuous spectrum is split up into a number of beads by irregularities in the Moon's surface. The relative intensities of these beads change considerably from exposure to exposure. This can be partly attributed to varying absorption by passing clouds, but oscillation of the image across the slit must also play a part, since of two beads of equal intensity in exposure II, the outer shows only a trace of continuous spectrum crossed by bright lines in III and IV, while the other still shows a strong Fraunhofer spectrum (Plate 5). It is clear that if a slitless spectrograph had been used, poor definition would have rendered the film almost valueless. But this advantage of a slit is partly set off by the fact that in imperfect atmospheric conditions the distance along the slit is a varying function from exposure to exposure of the effective height of bright lines. In good seeing conditions a slit helps to sort out different heights instead of dealing with integrated light as in an objective instrument; there is little gain in definition except for the lines rising to great heights, but it is just these lines which offer the most hopeful prospects for contour work. Finally, for studying

* Davidson and Stratton, *Mem. R.A.S.*, lxiv, 106, 1927.

† *M.N.*, 89, 566, 1929.

wave-lengths and the extreme limb spectrum the slit spectrograph with its constant resolving power undoubtedly possesses a great superiority.

The writer readily admits that even with a slit spectrograph a certain amount of scattering and superposition from the chromosphere is inevitable. Every extreme limb spectrum must be composite to some extent. Owing to the adverse conditions in which this film was obtained, the intensities in Table IV below and the contours in fig. 1 will suffer from the composite nature of the spectra. But the writer would like to stress the advantage of the slit spectrograph over objective instruments in studying the transition from absorption to emission, a problem which promises to be a very fruitful method of attacking that of the formation of absorption lines, yet one which has attracted comparatively little attention so far.

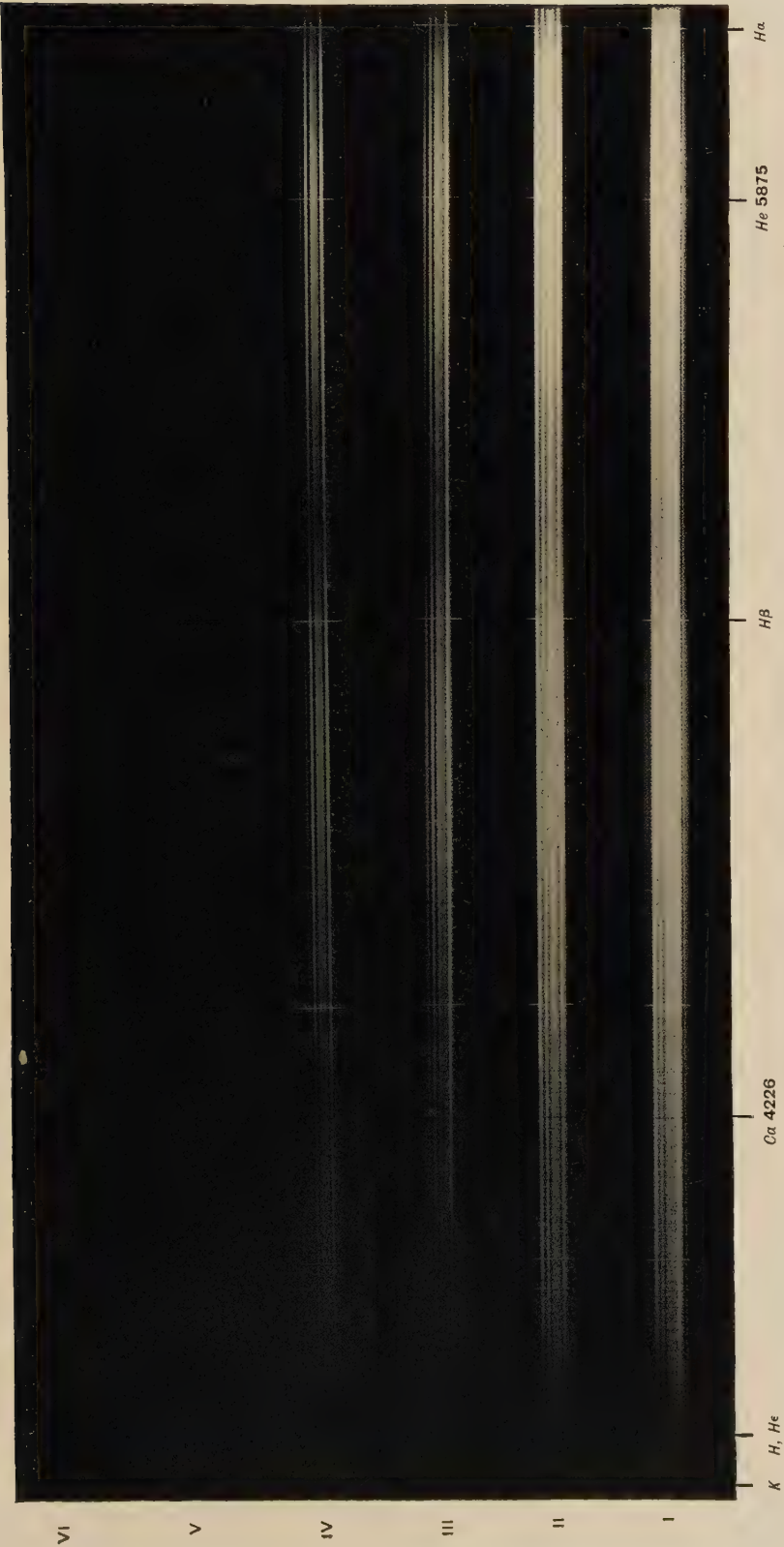
The one important deduction that can be made with certainty is that any absorption line observed in the extreme limb spectrum must be real. It is admittedly much more difficult to establish the existence of emission lines within the limb, but examination of this film has left little doubt in the writer's mind as to their reality. The grounds for this conclusion are (a) the different behaviour within the limb of lines such as *Ca* 4226, *Na* 5890, *Mg* 5183 and *Fe*⁺ 4233, which are approximately of the same strength in the flash; (b) the rare-earth lines, which although not particularly strong in the flash and confined to the low chromosphere, show clearly in emission over the photosphere as early as exposure I; their intensity, indeed, appears to be proportional to that of the continuous background.

The Transition from Absorption to Emission

Exposures I and II (−4.0 to −3.5 seconds and −3.1 to −2.6 seconds respectively).

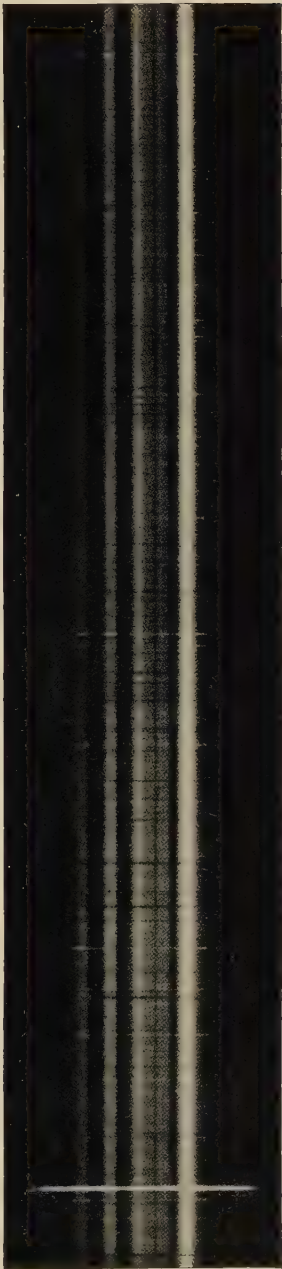
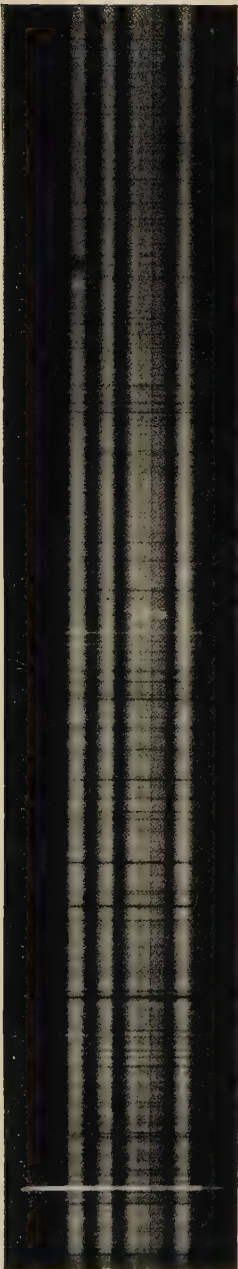
The bright hydrogen lines are visible extending to a height of about 10,000 km. and crossing the continuous as reversed emission lines, all traces of wing absorption having vanished. The same is true of the H and K lines except that some wing absorption is present. The absorption contours are measurable on exposure I (Plate 6 (d)) and yield equivalent widths (ignoring the central reversals) of 2.83 and 3.76 Å. respectively (ratio K/H = 1.33). As is well known, the wings overlap in the normal disc spectrum, and the great weakening at the limb is very noticeable. The central intensity of both lines, measured where the central reversals begin, is about 50 per cent.

Resonance lines of *Sr*⁺, *Ba*⁺ and *Sc*⁺ 4246 behave like hydrogen to a less degree, in showing reversed emission without wing absorption. The lines are single in the high chromosphere, and apparent duplicity sets in just before or after the limb is reached. This occurs very abruptly for the weaker lines, *Sr*⁺, *Ba*⁺ and *Sc*⁺, but extends to a height of about 5000 km. for H and K. The displacements of the violet and red components from the central absorption have been measured and are shown in Table I. The strength of the line is clearly the controlling factor. The violet component is usually the stronger of the two.



First six exposures taken by R. O. Redman with Moving Film Spectrograph from -4.0 to $+1.3$ seconds.
The rapid disappearance of the bright hydrogen lines is due to thickening cloud.

A. D. Thackeray, Wave-lengths and Intensities in the Flash Spectrum.



Fe^{+} 4629

He 4471

Fe 4383

$H\gamma$

Medium enlargement (region 4300 to 4650 Å.) of exposures II, III, and IV with Moving Film Spectrograph.

A. D. Thacheray, Wave-lengths and Intensities in the Flash Spectrum.

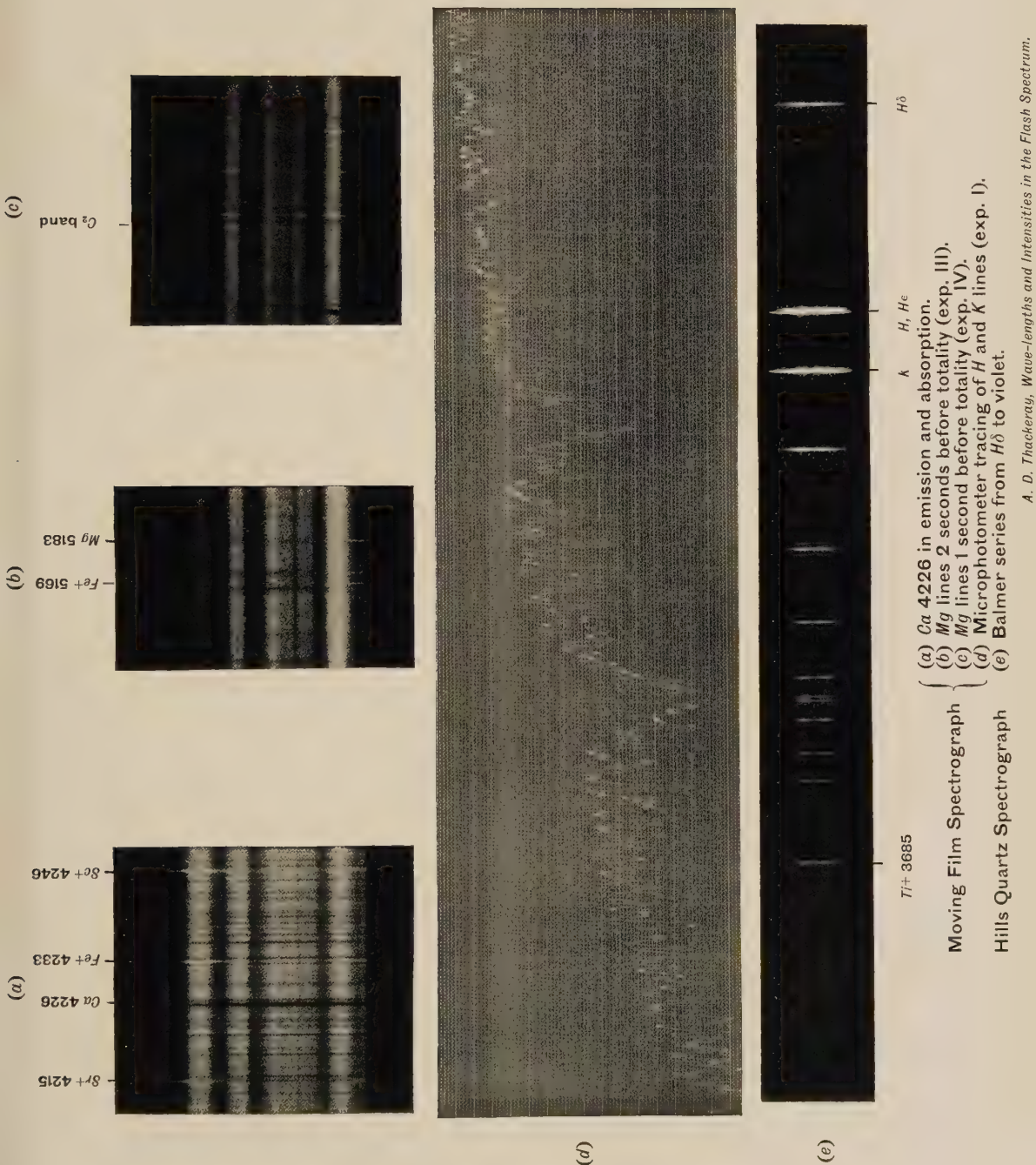


TABLE I

Displacements of Components of Reversed Lines (in Angstroms)

Line	Violet	Red Component
Ca ⁺ 3933	0.32	0.34
Ca ⁺ 3968	0.31	0.29
H 3970	0.13 :	0.14 :
Sr ⁺ 4077	0.29	0.27
H 4101	0.27	0.25
Sr ⁺ 4215	0.19 :	0.23 :
H 4340	0.32	0.29
H 4861	0.51	0.41

Helium and strong rare-earth lines appear as bright lines crossing the whole breadth of continuous spectrum. Lines of Fe^+ , Y^+ , Zr^+ show chromospheric emission with no trace of absorption or emission over the photosphere (in Fe^+ 4508 and 4583 faint absorption could just be detected). Nearly all the strong Ti^+ lines show faint absorption before merging into bright lines.

Exposure III (−2.2 to −1.6 seconds).

No trace of Ti^+ absorption is left; Fe^+ lines show traces of emission over the photosphere. Molecular lines of CH , weakly present, fade out, as the limb is approached, much more rapidly than atomic lines. The Mg “b” lines appear remarkably diffuse, and apparently the order of intensity is reversed from the normal, λ 5167 appearing the strongest with a fairly sharp core (Plate 6 (b)). This is no doubt mainly due to blending with Fe 5167.5. Even when this is allowed for, the intensities show a radical departure from the theoretical ratio 1 : 3 : 5 in agreement with Cherrington’s * observations. The third and fourth bands of C_2 at 5165 and 4737 Å. appear bright over the photosphere.

Exposure IV (−1.2 to −0.6 seconds).

The Mg “b” lines appear in emission over the photosphere (Plate 6 (c))—this is the only clear-cut case of this phenomenon observed for a neutral atom (apart from H and He). Mg 4571, a fairly prominent dark line in III, has disappeared abruptly. Mg 5528, 4703, 4167 belonging to the diffuse series, with excitation potential 4.3 volts, are easily visible as absorption lines. The D lines are barely visible in absorption. D_2 appears much stronger than D_1 and shows peculiar structure; this may be partly due to an overlying atmospheric line. Absorption lines Na 5682, 5688 and 4982 in the subordinate series $3^2P^\circ - n^2D$ are considerably stronger than D_2 and D_1 .

Ca 4226, the strongest line in the whole region $H\delta$ to $H\alpha$ in previous exposures, appears diffuse and at the extreme limb is weaker than Fe 4383. Subordinate lines Ca 5857, 6102, 6122, 6162, present up to and including III,

* *L.O.B.*, 17, 161, No. 477, 1935.

can no longer be detected. The multiplets $4^3P^o - p^2\ 3P$, $4^3P^o - 4^3D$ are still strongly represented, the strongest lines being nearly as intense as 4226.

The persistence of absorption lines of the neutral elements, excluding hydrogen, so near the limb is remarkable (according to elementary theory, lines formed by true absorption should disappear at the limb). In all about 220 absorption lines have been identified on this exposure; of these, 64 lying between 4100 and 4500 Å. have been measured photometrically for equivalent widths. The calibration curves for the photometric work were taken from the wedge exposure ($\frac{1}{4}$ second) on the centre of the disc; the mirror was diaphragmed for this exposure. With the exception of a few weak lines whose error of measurement is large, all lines are weakened from centre to limb, the ratio centre/limb varying from 6 to 1. The degree of weakening appears to depend almost entirely on line strength; no dependence on excitation potential is detectible. It is thus impossible to derive a limb-temperature by the Russell-Adams method.

Table II shows the ratio centre/limb widths for lines grouped according to width at the centre. The equivalent widths at the centre of the disc were taken from Allen's table; * measures of a few of the stronger lines, including *Ca* 4226, in the exposures from the eclipse film on the centre of the disc showed satisfactory agreement with Allen's measures.

TABLE II

Limb-weakening of Absorption Lines ($\cos \theta = 0.99937$)

Mean Width at Centre (Angstroms)	Ratio Centre/Limb	Number of Lines
1.00	5.4	5
0.59	4.6	3
0.42	2.9	4
0.33	3.0	5
0.24	3.1	6
0.16	2.0	9
0.11	1.9	16
0.08	1.8	16

The limb spectrum photographed without an eclipse suffers from scattered light from the disc, and the weakening of absorption lines tends to be masked. In eclipse photographs the danger lies in the opposite direction, since scattered and superposed light from the chromosphere will tend to fill in the lines. It is possible that the systematic run of the ratio centre/limb in Table II is attributable to this cause, the strongest lines being also strong in the chromosphere. However, the H and K lines give a centre/limb ratio of 4 : 1 on exposure I, and doubtless would give a much higher value, if it were measurable, for exposure IV, and here the weakening is mainly in the wings, the chromospheric emission being much narrower than the absorption lines. On these grounds it would appear that strong

* *Mem. Commonwealth Solar Obs.*, No. 5, 1934.

lines really are weakened more than weak lines at the limb independent of scattered light from the chromosphere.

Exposure V (–0.2 to 0.4 second).

The very faint strip of continuous spectrum has been thoroughly searched for traces of absorption lines. Apart from signs of water-vapour absorption in the red, only three doubtful lines were found coinciding with strong lines in IV; these were *Fe* 4222 (E.P. 2.4 volts), *Ca*, *Ti* 4318 and *Fe* 4383. Consideration of the previous exposures leads one to believe, however, that if more light had been available, the existence of many more lines at this extreme portion of the limb would have been established.

The transition from absorption to emission of three typical lines, *Ca* 4226 (typical of neutral metals), *Fe*⁺ 4233 (typical of ionised metals, rare earths and helium) and *Sr*⁺ 4215 (typical of *H*, *Sc*⁺ and *Ba*⁺) is illustrated in fig. 1. The diagrams are based on photometric measures of microphotometer tracings taken at a large number of points of exposures II, III and IV. The intensity of the continuous spectrum diminishes by half in each successive figure from (a) to (d), (e) corresponding to a point just outside the limb. It should be emphasised that the figures only refer to average behaviour, as intensity of the continuous appears to be an unreliable criterion for the strength of an absorption or emission line. Such irregularities may be attributed to the poor seeing, but also perhaps to real solar disturbances; a low-lying prominence reveals itself by distortion at one extremity of the hydrogen lines. The behaviour of the central intensity is interesting. In *Ca* 4226 it remains practically constant until the limb is reached, and then increases rapidly in the low chromosphere; there are indications of reversals, as shown in (b) and (e) on some tracings and to the eye in the microscope. In *Fe*⁺ and *Sr*⁺ there is a decrease within the limb and then again a sudden increase outside. The lines *Fe* 4383 and *Cr* 4254 have also been found to give brighter central intensities in the chromosphere than in absorption at the extreme limb. Since these measures are made without correction for resolving power the effect is probably still more marked; the only danger that must be borne in mind is that cloud absorption may have been heavier over the photosphere than over the chromosphere.

It is particularly interesting to find the *Mg* triplet bright over the photosphere at the same time as absorption lines 5528, 4703, 4167 Å. of the diffuse series ($3^1P^\circ - n^1D$), excitation 4.3 volts. Atoms must be maintained in the 3^1P° state by absorption of the resonance line 2852 Å., which must be very strong. In sodium the subordinate series ($3^2P^\circ - n^2D$) is still clearly visible in absorption when the D lines ($3^2S - 3^2P^\circ$) have nearly vanished. The *Ca* triplet $4^3P^\circ - 5^3S$ in the red vanishes about the same time as its analogue, the *Mg* triplet, but the lines $4^3P^\circ - 4^3D$, $4^3P^\circ - p^2\ ^3P$, with the same ground state persist* much longer. These observations emphasise the delicate balance between emission and absorption in the extreme limb spectrum, and suggest that the most persistent subordinate lines are those

* "Persistence," as used here, always refers to the visibility of an absorption line as one proceeds towards the extreme limb.

whose lower state is connected with the ground state by a strong resonance line. Apart from a few exceptions of this sort, the limb spectrum is remarkably similar to the normal disc spectrum, as far as the neutral metals are concerned, with the gradient of intensity (between strong and weak lines) much diminished. The outstanding feature of the limb spectrum is the disappearance of the hydrogen lines and the ionised metals.

Elementary theory of absorption lines with η constant with depth predicts that lines formed by pure absorption ($\epsilon = 1$) should disappear at the limb, and those formed by pure scattering ($\epsilon = 0$) should persist. The fact that neutral metals persist, although considerably weakened, is in agreement with Pannekoek's* argument that at the centres of lines we observe light from such high levels that the collision factor can be neglected—this should be true *a fortiori* at the limb. But the disappearance of the lines of hydrogen and ionised metals, rising to much greater heights, leads to the improbable conclusion that for these lines the collision factor is large. The solution of this difficulty is probably to be found in a development of B. Strömgren's† theory of absorption lines, which includes particular consideration of electron captures and departures from thermodynamical equilibrium. Woolley‡ has found that the assumption of constant η breaks down for ionised atoms, and it would therefore be of special interest to consider the effects of variable η on the formation of lines at the limb.

Comparison of Wave-lengths of Emission and Absorption Lines

Menzel § has found from slitless spectra that many flash lines are displaced to the violet relative to the Fraunhofer lines at the limb, and that this occurred whether the crescent was concave to the red or violet. Measurements of wave-length with a slit spectrograph should be more reliable, and a great many lines have therefore been measured on this film to study this effect. Its existence has been confirmed particularly for *Ca* 4226, which shows a relative shift of 0.046 Å. (about 0.01 mm. on the plate). Results are shown in Table III for 24 unblended lines in the region to the violet of 4500 Å. where the dispersion is suitable for these measures. The only eight other lines in this region which were visible both in emission and absorption on the same exposure have been excluded on the ground of serious blending. The mean difference in wave-length (absorption-emission) is +0.021 Å. As no comparison spectrum is available, the flash lines of *Ti*⁺ and *Fe*⁺ showing no reversal have primarily been used as standards. Lines were measured at a number of points—emission “above” and “below,” absorption “above” and “below” and in the central strip; at each point the distance from the centre was noted and a correction for the curvature of the lines applied. The theoretical curvature was used, after being checked by measurement of an *Fe* arc spectrum, with the

* *M.N.*, **91**, 158, 1931.

† *Z.f.Ap.*, **10**, 237, 1935.

‡ *M.N.*, **92**, 495, 1932.

§ *Lick Obs. Publ.*, **17**, 299, 1931.

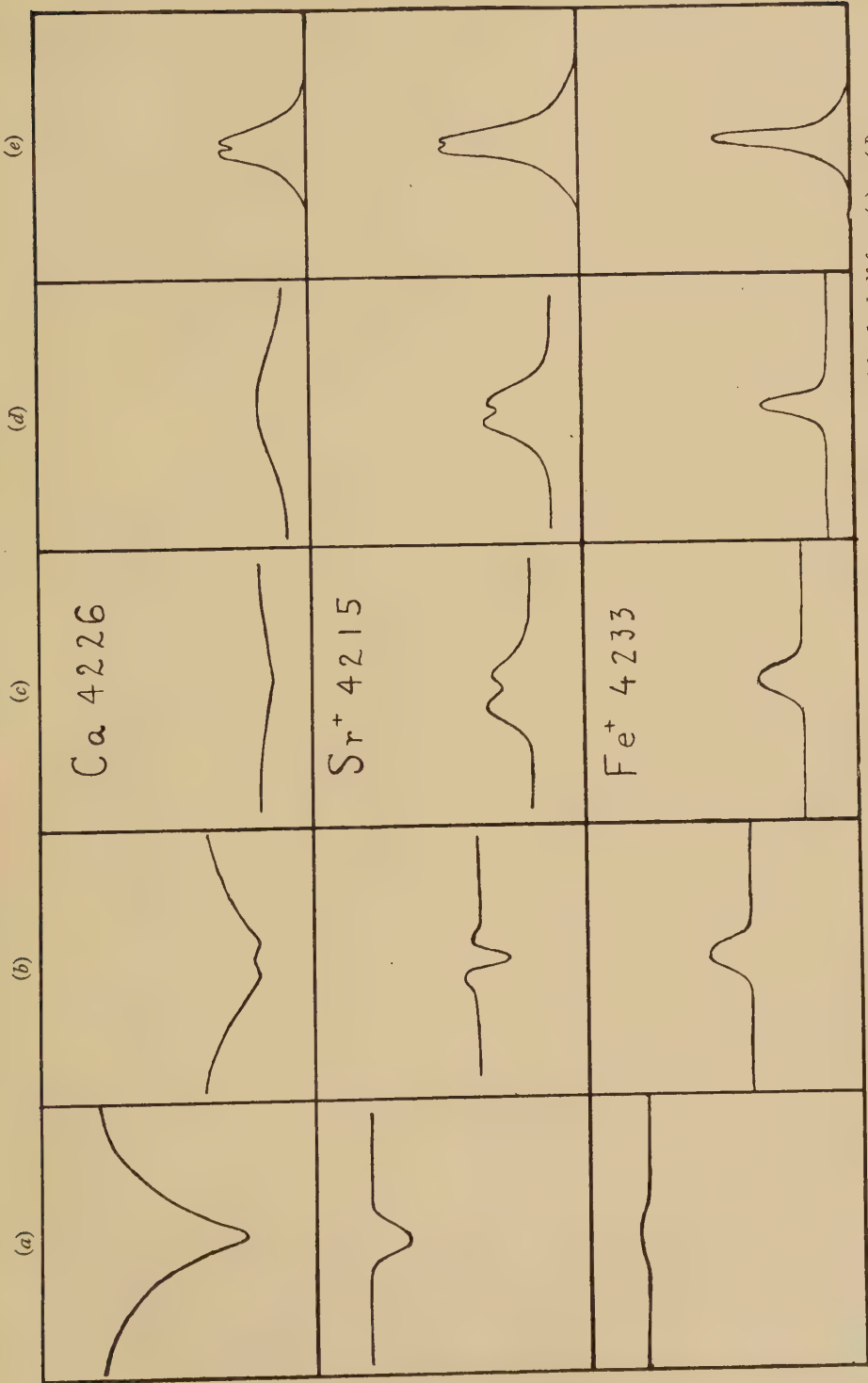


FIG. 1.—Transition from emission to absorption. The intensity of the continuous spectrum diminishes by half from (a) to (d); (e) corresponds to a point just outside the limb.

assumption that the image of the disappearing crescent had been centred on the axis of the collimator, *i.e.* that the parabolic arcs had their vertices at the mid-point of the continuous spectrum. This assumption could be roughly checked by measurement of the curvature of a line like *He* 4471, which was visible over a long arc running right across the continuous spectrum. The measures of this line and of the *Fe* arc lines are shown in fig. 2, and it appears that the image must have been centred within 1 mm. of the collimator axis.* An error of this order would produce an error of 0.002 Å. in the relative shift of emission and absorption lines, and is therefore negligible. The actual correction applied amounted at most to 0.0035 mm., corresponding to 0.023 Å. at *H γ* . Since the curvature is to the violet, the application of the correction reduced the apparent shift. In mounting the film in the micrometer optically plane glass was used between film and microscope.

TABLE III

Relative Displacements of Emission and Absorption Lines

λ	$\Delta\lambda$ (unit 0.001 Å.) (Absorption- Emission)	λ	$\Delta\lambda$ (unit 0.001 Å.) (Absorption- Emission)
<i>Sr</i> ⁺ 4077	+ 4	<i>Fe</i> 4325	+ 30
<i>Sr</i> ⁺ 4215	- 3	<i>Fe</i> 4375	+ 50
<i>Ca</i> 4226	+46	<i>Fe</i> 4383	+ 29
<i>Sc</i> ⁺ 4246	+29	<i>Fe</i> 4404	+ 35
<i>Fe</i> 4250.1	- 14	<i>Ca</i> 4425	+ 28
<i>Fe</i> 4250.8	+ 8	<i>Fe</i> 4442	+ 28 :
<i>Cr</i> 4254	+ 22	<i>Fe</i> 4447	- 29 :
<i>Fe</i> 4271.1	- 14	<i>Ca</i> 4454	+ 34 :
<i>Fe</i> 4271.8	+ 33	<i>Fe</i> 4494	+ 46 :
<i>Cr</i> 4274	+ 24	<i>Fe</i> 4528	+ 54 :
<i>Ca</i> 4302	+ 8	<i>Ba</i> ⁺ 4554	- 3 :
<i>Sc</i> ⁺ 4325	+ 54 :	<i>Mg</i> 4703	+ 30 :

Weighted Mean +0.021 $\pm$ 0.010 Å. (half-weight to values with colon).

Lines in Region of Low Dispersion.

λ	$\Delta\lambda$ (unit 0.01 Å.)
<i>Fe, Mg</i> 5167	+7 :
<i>Fe, Mg</i> 5172	0
<i>Mg</i> 5183	0
<i>Na</i> , atm. 5889	+4 :
<i>Na</i> 5895	0

* The scatter in the measurements of *He* 4471, especially near the vertex, can probably be attributed to random distortion of the line. Twenty emission lines which were noted as suffering peculiar distortion, frequently of the same pattern, were found, after identification, to be due to *H*, *He* or ionised atoms, *i.e.* all high-level lines; the lines in Table III are nearly all low-level lines and appear sharp and undistorted. To this extent the observations are consistent with Menzel's interpretation of contours at high levels in terms of turbulence.

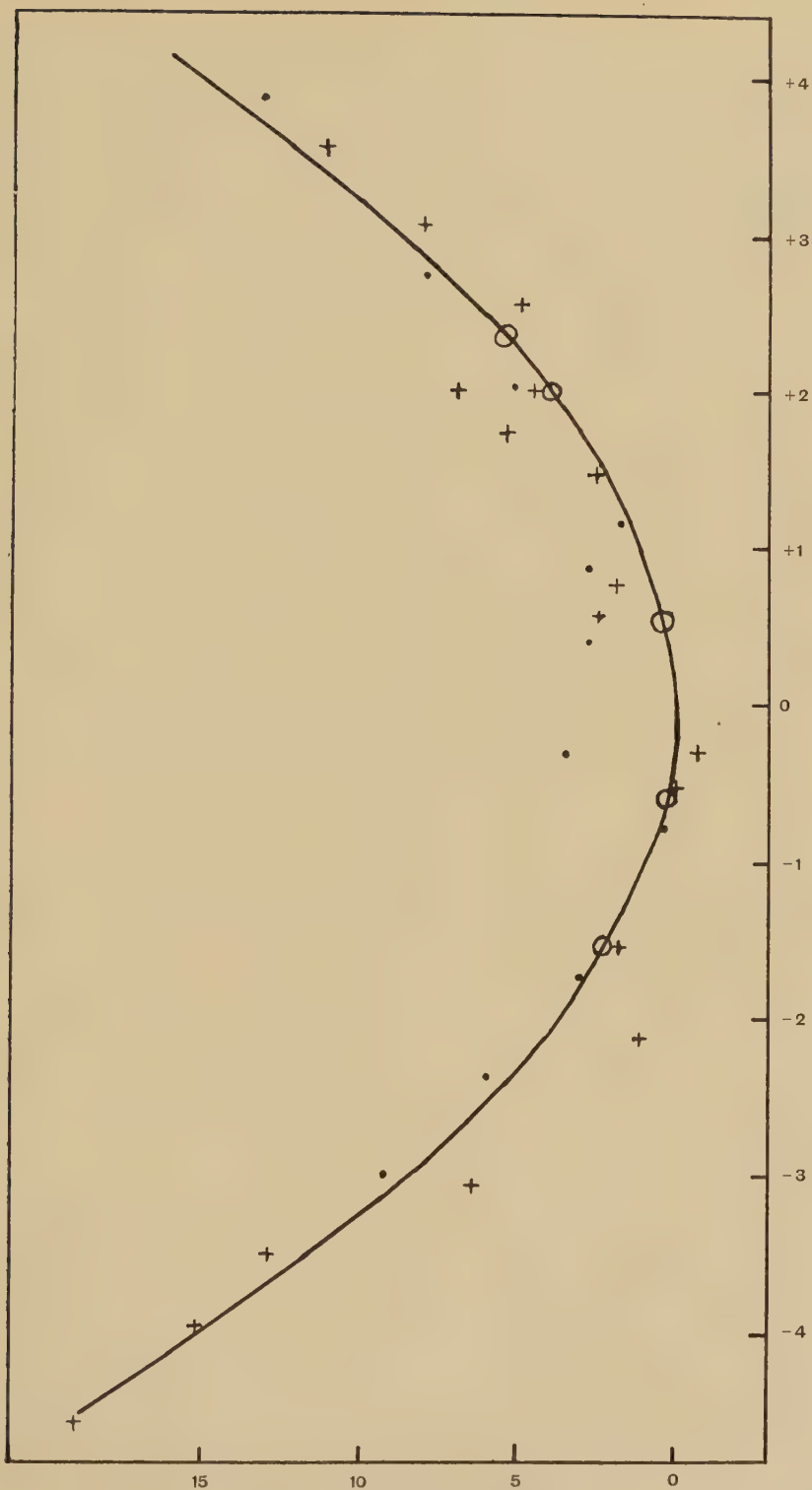


FIG. 2.—Curvature of slit image.

Unit of ordinates: 1 mm.

Unit of abscissæ: 0.001 mm.

+ Arc lines.

● He 4471.

○ Points at which emission and
absorption lines were measured.

Reversing the plate in the micrometer should eliminate accidental errors due to lack of straightness in the cross-wire provided the positions "above" and "below" are symmetrical in the field of the eyepiece, but as a precaution measures were also made with the cross-wire rotated through 180° . Since two measures were made with each position of plate and cross-wire, measurement of an absorption line entailed 24 settings, of an emission line 16 settings in all. Measurements of a positive gave the same results, so that the shift cannot be attributed to a physiological cause.

One further point must be noted. It is possible that even with a slit spectrograph a spurious shift of this nature might arise through irregular illumination of the slit, the chromosphere falling on one side and the edge of the photosphere on the other. The set-up of the instrument happened to be such that, if this were so, the flash lines at second contact would appear shifted in the observed direction. This explanation may be rejected by a number of considerations. We have already found evidence that the image oscillated considerably across the slit during the various exposures, and Dr. Redman and the writer agree that the seeing deteriorated very rapidly during the last seconds before totality. Moreover, if this explanation is correct, the shift should be greatest for lines of greatest extent, and this is directly contrary to observation. Finally, such a shift should be linearly the same at all wave-lengths regardless of dispersion and should therefore increase rapidly in wave-length units towards the red. The absence of a measurable shift for the *Mg* "b" lines and the D lines affords a convincing proof that the effect cannot be attributed to this cause.

A greater number of lines are available if we do not restrict ourselves to those visible in emission and absorption on the same exposure. Residuals (limb-centre) for 36 unblended lines of neutral absorption lines give a mean residual $+0.009 \pm 0.010$ A.; 16 lines of neutral atoms observed in emission give a mean residual (chromosphere-centre) -0.009 ± 0.010 A. For this comparison with the centre it must be remembered that chromospheric lines have been used as standards with wave-lengths as given in the Revised Rowland for the centre of the disc. Since the residuals are slightly smaller than the probable error, one cannot draw definite conclusions, but the results suggest that the emission and absorption lines are symmetrically placed on either side of their normal wave-lengths.

The relative shift of emission and absorption lines is consistent with the asymmetrical reversals observed in the Balmer lines (see Table I). No explanation for the effect can be offered at present; it is possible that the chromospheric lines happened to arise in a layer with motion in the line of sight, but the measures were made far from the area of disturbance due to the prominence. This is in any case an unsatisfactorily arbitrary explanation. The evidence of this film suggests the conclusion that the chromospheric lines do not share the well-known red shift observed in absorption lines at the limb; if anything, they show a violet shift which would intensify the apparent red shift of the Fraunhofer lines. Since the relative displacements are only just within the limit of observation for most lines it is highly desirable to attack the problem with higher dispersion.

Table IV gives details of wave-lengths and intensities in the extreme limb spectrum from exposures III and IV on which the data of Tables II and III are based. Lines which could be observed in emission alone have been omitted in general as being of little interest (except in so far as they provided standards in the wave-length reductions; the results of Table III do not, of course, depend on the accuracy of standards).

The explanation of the table is as follows:—

Columns 1, 4 and 5: wave-length, identification and intensity from the Revised Rowland Catalogue.

Columns 2 and 3: wave-length in absorption (limb) and emission (flash) measured on exposures III and IV.

Columns 6 and 7: eye estimates of intensity from III and IV. Special notations: * intensity from III alone, not measurable on IV; *n*=diffuse; *s*=sharp; *d*=double; *a*=asymmetrical; *p*=peculiar. Many lines with this latter characteristic could only be observed over a small part of the width of the continuous spectrum, sometimes giving the curious impression of being reduced to a mere point; this behaviour could usually be traced to an effect of blending with a rare-earth line which reverses early and tends to wash out its neighbour.

The first part of the table, as far as 4500 Å., has an eighth column with the equivalent width in absorption (unit 0.01 Å.) from exposure IV. A colon, as usual, denotes a measure of low weight.

TABLE IV

λ			Element	Intensity			
Disc	Limb	Flash		D	L	F	W
4077.726	.744	.740	<i>Sr</i> ⁺	8	5 <i>n</i> *	8 <i>n</i>	
4101.750		.751	<i>H</i>	40		70	
29.732		.735	<i>Eu</i> ⁺	1		6	
32.069	.061		<i>Fe</i>	10	10		19
43.880			<i>Fe</i>	15			17
47.677			<i>Fe</i>	4			9
67.279	.275		<i>Mg</i>	8	3*		4
74.919	.938		<i>Fe</i>	4	5		
81.766			<i>Fe</i>	5			8
87.049	.036		<i>Fe</i>	6	8*		8
91.439	.461		{ <i>Fe</i>	6	4 <i>p</i>		10
91.685			{ <i>Fe</i>	3			
98.246			{ <i>Fe</i>	4			
4198.338	.30		{ <i>Fe</i>	4	5 <i>s</i>		
4202.042	.065		<i>Fe</i>	8	9		17
06.704	.701		<i>Fe</i>	3	3		
10.337	.36		{ <i>Fe</i>	4	6		10
10.404			{ <i>Sa</i> ⁺	3			
15.545	.529	.532	<i>Sr</i> ⁺	5	3*	20	
22.223	.260		<i>Fe</i>	5	10		11
26.742	.760	.714	<i>Ca</i>	20	12	4 <i>n</i>	21
35.738	.956	.887	{ <i>Y</i> ⁺	0		3 <i>nd</i>	12
35.951			{ <i>Fe</i>	8	5		
46.838	.865	.836	<i>Sc</i> ⁺	5	2*	20	

TABLE IV—continued

λ			Element	Intensity			
Disc	Limb	Flash		D	L	F	W
4250.132	.145	.159	<i>Fe</i>	8	8	2	10
50.799	.816	.808	<i>Fe</i>	8	8	2	14
54.348	.363	.341	<i>Cr</i>	8	6*	4 ⁿ	10
60.488		.51	<i>Fe</i>	10		5 ⁿ	9
71.166	.146	.16	<i>Fe</i>	6	4	2	9
71.776	.778	.745	<i>Fe</i>	15	12	3	20
74.808	.803	.779	<i>Cr</i>	7	8	4	10
82.413	.434		<i>Fe, Pr⁺</i>	5	4 ^{ps}		5
83.016	.024		<i>Ca</i>	4	8		8
89.731		.735	<i>Cr</i>	5		3	7 :
91.475	.469		<i>Fe</i>	2	3		9
4298.996			<i>Ca</i>	3			10 :
4302.541	.558	.55	<i>Ca</i>	4	8	2	8
07.749 }	.88	.90	{ <i>Ca</i>	3 }	12	6 ⁿ	14
07.914 }			{ <i>Fe, Ti⁺</i>	6 }			
09.383			<i>Fe, CH</i>	3			6
14.093	.11	.185	<i>Sc⁺, CH</i>	3	1*	12 ⁿ	
14.979 }	.00	.968	{ <i>Ti⁺</i>	3 }			
15.100 }			{ <i>Fe</i>	4 }	1*		4
18.660	.677		<i>Ca, Ti</i>	4	5		6
25.777	.790	.760	<i>Fe</i>	8	8 ^a	4	14
37.057	.06		<i>Fe</i>	5	8		7
40.477	.47	.469	<i>H</i>	20	1*	100	
67.592 }			{ <i>Fe</i>	5 }			6
67.682 }		.64 :	{ <i>Ti⁺</i>	2 }		2 ⁿ	
67.914	.86		{ <i>Fe</i>	2 }	2		6
69.781			<i>Fe, CH</i>	4			5
71.288			<i>Cr</i>	2			6
75.946	.97	.92	<i>Fe</i>	6	4	7	
79.240			<i>V</i>	4			6
83.559	.561	.530	<i>Fe</i>	15	20	5 ⁿ	20
84.714			<i>V</i>	3			8
4389.256	.22		<i>Fe</i>	2	3 ^p		
4404.763	.809	.774	<i>Fe</i>	10	12 ^a	5 ⁿ	20
07.65 }		.70	{ <i>V, Ti⁺</i>	2 }			
07.71 }	.75		{ <i>Fe</i>	4 }		3	8
08.21 }			{ <i>V</i>	2 }			
08.43 }			{ <i>Fe</i>	3 }			8
15.137	.138		<i>Fe</i>	8	10		15
25.446	.469	.441	<i>Ca</i>	4	2	2	10
27.11 }			{ <i>Ti</i>	2 }			
27.32 }	.29	.287	{ <i>Fe</i>	5 }	3	8 ⁿ	7
30.20			<i>Fe</i>	1			4
30.62	.60		<i>Fe</i>	3	4		7
34.97 }	.06	.00	{ <i>Ca</i>	5 }	12	5 ⁿ	13
35.16 }			{ <i>Fe</i>	2 }			
35.69		.56 :	<i>Ca, Eu⁺</i>	4		4	4
39.89			<i>Fe</i>	1			5
42.35	.40 :	.37	<i>Fe</i>	6	1	1	9
45.48			<i>Fe</i>	1			5
47.73	.75	.78 :	<i>Fe</i>	6	2	2 ⁿ	10

TABLE IV—continued

λ			Element	Intensity			
Disc	Limb	Flash		D	L	F	W
4450.32			<i>Fe</i>	1			3
54.39			<i>Fe</i>	3			7
54.80	.83	.80	<i>Zr⁺, Ca</i>	5	2a	3n	10
55.82	}	.83	<i>Mn</i>	2		1	8
55.90			<i>Ca</i>	3			
56.63			<i>Ca</i>	2			4 :
59.04	}	.15	<i>Ni</i>	2			
59.14			<i>Fe</i>	3		3	10
61.66			<i>Fe</i>	4		5	8
62.01		.66	<i>Fe, Mn</i>	3			6
66.56		.56	<i>Fe</i>	5		4p	8
69.16	}	.27	<i>Ti⁺</i>	1		1n	
69.38			<i>Fe</i>	4			3
70.14			<i>Mn</i>	1			3
82.18	}	.22	<i>Fe</i>	5	3	4	12
82.28			<i>Fe</i>	3			
84.23			<i>Fe</i>	4			4
89.75	.75		<i>Fe</i>	4	2		8
94.57	.60	.55	<i>Fe</i>	6	3	2	3 :
4496.86			<i>Cr</i>	3			3 :
4528.63	.69	.64	<i>Fe</i>	8	3	4n	
31.16	.20		<i>Fe</i>	5	1*		
33.25	.16 :	.22	<i>Ti</i>	4	1*	1	
52.46	}	.43 :	<i>Ti</i>	2	1*	1n	
52.56			<i>Fe</i>	1			
54.04	.04	.05	<i>Ba⁺</i>	8	3*	20	
68.77	.77		<i>Fe</i>	1	3*		
81.40	}	.49	<i>Ca</i>	4	3*	2	
81.52			<i>Fe</i>	4			
85.88			<i>Ca</i>	4	3		
92.53	}	.64	<i>Ni</i>	2			
4592.66			<i>Fe</i>	4	4*		
4600.76	.76		<i>Cr</i>	3	1		
02.95	.92	.94	<i>Fe</i>	6	2	1	
11.29	.29		<i>Fe</i>	5	2*		
13.21	}	.27 :	<i>Fe</i>	3	2*	2	
13.37			<i>Cr, La⁺</i>	3			
16.13	.07 :		<i>Cr</i>	4	1*		
32.82	}	.84	<i>?</i>	1	2	2	
32.93			<i>Fe</i>	4	4		
37.51	.43 :	.91	<i>Fe</i>	5	1n		
54.51	}	.58	<i>Fe</i>	4		4n	
54.63			<i>Fe</i>	5	5		
63.18			? <i>Fe</i>	0	2		
80.31	}	.34	<i>Fe</i>	1	0		
80.49			<i>Fe, Cr</i>	1			
4685.28	.32		<i>Ca</i>	2	1		
4703.00	.98	.95	<i>Mg</i>	10	8	3	
07.29	}	.38	<i>Fe</i>	5	3		
07.50			<i>Fe</i>	2			
33.60	.65	.64	<i>Fe</i>	4	2	1	

TABLE IV—continued

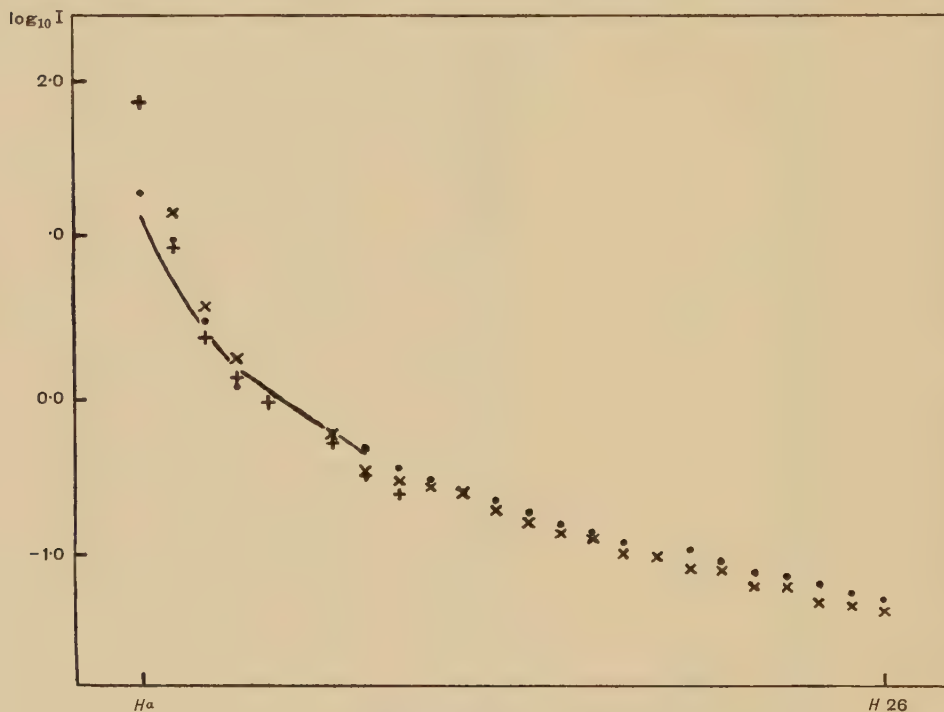
λ			Element	Intensity		
Disc	Limb	Flash		D	L	F
4754.04	.09		<i>Mn</i>	7	3^n	
63.92	.08 :	.92 :	<i>Ni, Ti</i> ⁺	4	0	2
68.41	.51 :		<i>Fe</i>	2	0	
4783.43	.40	.44	<i>Mn</i>	6	2^n	3^n
4823.52	.52		<i>Mn</i>	5	2^*	
29.03	.07 :		<i>Ni</i>	3	0	
71.33	.32		<i>Fe</i>	5	I	
72.15	.05 :		<i>Fe</i>	4	3^n	
78.13	.07 :		{ <i>Ca</i>	3	3	
78.23			{ <i>Fe</i>	4		
4890.76	.75		<i>Fe</i>	6	I	
4903.26	.27		{ <i>Cr</i>	0	2	
03.32			{ <i>Fe</i>	5		
10.33	.38		{ <i>Fe</i>	2	I	
10.57			{ <i>Fe</i>	2		
19.00	.94		<i>Fe</i>	6	2^*	
20.52	.49		<i>Fe</i>	10	4^*	
34.04	.05	.10	{ <i>Ba</i> ⁺	3	3^*	6
34.10			{ <i>Ba</i> ⁺	4		
38.82	.84		<i>Fe</i>	4	I	
46.40	.41		<i>Fe</i>	3	I	
50.11	.09		<i>Fe</i>	2	0	
57.31	.55	.50	{ <i>Fe</i>	5	8	3^n
57.61			{ <i>Fe</i>	8		
66.10	.13		<i>Fe</i>	4	2	
82.83	.84		<i>Na</i>	2	2	
91.07	.99 :		<i>Ti</i>	3	0	
4994.14	.11		<i>Fe</i>	3	0	
5005.72	.01		{ <i>Fe</i>	4	2	
06.12			{ <i>Fe</i>	5		
07.22	.23		<i>Ti</i>	3	I	
24.85	.89		<i>Ti</i>	3	I	
41.62	.68		{ <i>Ca</i>	2	I	
41.76			{ <i>Fe</i>	4		
49.83	.89		<i>Fe</i>	6	I	
72.68	.88		{ <i>Fe</i>	2	I	
72.92			{ <i>Cr</i>	1		
5098.71	.72		<i>Fe</i>	3	0	
5107.46	.54	.55	{ <i>Fe</i>	4	I	I
07.65			{ <i>Fe</i>	4		
10.41	.34 :		<i>Fe</i>	5	0	
23.	.05		?		2	
27.37	.37 :		{ <i>Fe</i>	3	2^n	
27.69	.58 :		{ <i>Fe</i>	-1		
37.08	.21		{ <i>Ni</i>	3	2	
37.39			{ <i>Fe</i>	3		
39.26	.24		{ <i>Fe</i>	4	5	
39.47			{ <i>Fe</i>	4		
42.94	.85		<i>Ni, Fe</i>	2, 3	I	
51.92	.86		<i>Fe</i>	3	I	
55.13	.92 :		<i>Co, Ni</i>	-3, 1	0	
62.28	.02 :		<i>Fe</i>	5	I	
67.33	.42	.37	<i>Mg, Fe</i>	15, 5	7^n^*	7

TABLE IV—*continued*

λ			Element	Intensity		
Disc	Limb	Flash		D	L	F
5172.70	.66	.69	Mg	20	6n*	10
5183.62	.60	.62	Mg	30	6n*	15
5203.35	.34		Fe	6	0	
04.51	.69:		{ Cr	5	0	
04.60			{ Fe	3		
06.05	.06		Cr	5	1	
08.43	.49		{ Cr	5	1	
08.60			{ Fe	2		
25.53	.54		Fe	2	1	
26.87	.03		{ Fe	3	1n	
27.19			{ Fe	5		
29.86	.85		Fe	4	1	
32.95	.95		Fe	7	4	
47.06	.16		{ Fe	1	1d	
47.58			{ Cr	2		
50.22	.39		{ Fe	2	1	
50.66			{ Fe	3		
69.55	.65		Fe	8		
70.27	.27		{ Ca	3	3np	
70.39			{ Fe	4		
81.80	.65 :		Fe	5	0	
5296.70	.78 :		Cr	3	1	
5300.75	.76		Cr	2	1s	
28.05	.02		Fe	8	4	
41.03	.73		?Fe	7	1	
83.38	.34		Fe	6	1p	
5397.14	.06		Fe	7	2	
5404.15	.14		Fe	5	0	
05.79	.79		Fe	6	2	
09.80	.73		Cr	4	2	
29.71	.75		Fe	6	2nd	
34.54	.51		Fe	5	1	
46.59	.86		{ Ti	2		
46.92			{ Fe	6		
55.63	.62		Fe	4	3	
76.58	.80		{ Fe	3	1	
5476.92			{ Ni	5		
5501.48	.32 :		Fe	5	0	
06.79	.85		Fe	5	1*	
28.42	.35		Mg	8	2	
86.77	.75		Fe	7	1s	
88.77	.64		Ca	6	1	
98.31	.38		{ Fe	1	1	
5598.49			{ Ca	4		
5602.87	.89 :		{ Ca	3	1	
02.97			{ Fe	4		
15.31	.34		{ Fe	2	2	
15.66			{ Fe	6		
82.65	.51 :	.56	Na	5	1	4n
5688.22	.02 :		Na	6	1	
5889.98	.97	.93	Na	30	5*	15
5895.94	.92	.92	Na	20	5*	12

Photometry of Chromospheric Lines

Owing to the cloudy conditions few results of value can be obtained relating to photometric problems, but such work as has been attempted has been instructive in some of the difficulties that have to be met. Fig. 3 shows the Balmer decrement yielded by measures of the exposures with the moving film and Hills quartz spectrographs. The black-body calibration was obtained by using the exposures on the centre of the disc (0.01 and



than that found by other observers, but the measure of $H\alpha$ was rendered unreliable through two difficulties—lack of perfect definition in this region, and very great contrast in the characteristic curve. It is desirable in measuring the ratio $H\alpha : H\beta$ to use an emulsion with as nearly as possible the same characteristic curve at the two wave-lengths ; soft development would help in this direction.

Intensities of a number of multiplets of Fe^+ , Ti^+ and Mg are given in Table V.

TABLE V

Multiplet Intensities in Flash

Multiplet	λ	Flash Int.	Theory
$Fe+b^4F - z^4F^o$	4489.21	23	51
	4491.41	26	154
	4515.34	30	198
	4520.24	30	40
	4555.90	38	293
	4582.84	24	51
$Fe+b^4F - z^4D^o$	4508.29	33	70
	4522.64	34	112
	4541.52	23	28
	4576.31	26	37
	4583.84	49	250
$Ti+a^2G - z^2F^o$	4468.49	42	70
	4501.27	42	56
$Ti+a^2P - z^2D^o$	4563.77	47	10
	4589.96	26	2
$Mg\ 3^3P^o - 4^3S$	5167.30	1 1	1
	5172.67	1.4 1.5	3
	5183.60	1.7 1.9	5

The intensities all refer to the low flash ; the radical departures from the theoretical gradient confirm the results of Pannekoek and Minnaert * in similarly low levels. The two sets of intensities for the Mg triplet (on a different scale from the other lines) refer to different levels ; the first was taken inside gaps in the continuous spectrum and must belong to a lower level ; the difference in gradient is appreciable.

Widths of Chromospheric Lines

The contours of a number of lines in the low chromosphere have been measured. In fig. 4 the mean contour of nine unblended Ti^+ and Fe^+ lines in the region of 4500 A. is shown together with that of $He\ 4471$ and $H\gamma\ 4340$. The effective height cannot be greater than 2000 km. and is probably considerably less. No systematic change of contour with height could be detected, except that the hydrogen lines were broader at the

* *Verh. d. K. Akad. Wet. Amsterdam*, xlii, No. 5, 78, 1928.

prominence level, and here the distortion could be seen with the unaided eye. The measured "half-width" (*i.e.* the total width at 50 per cent. of

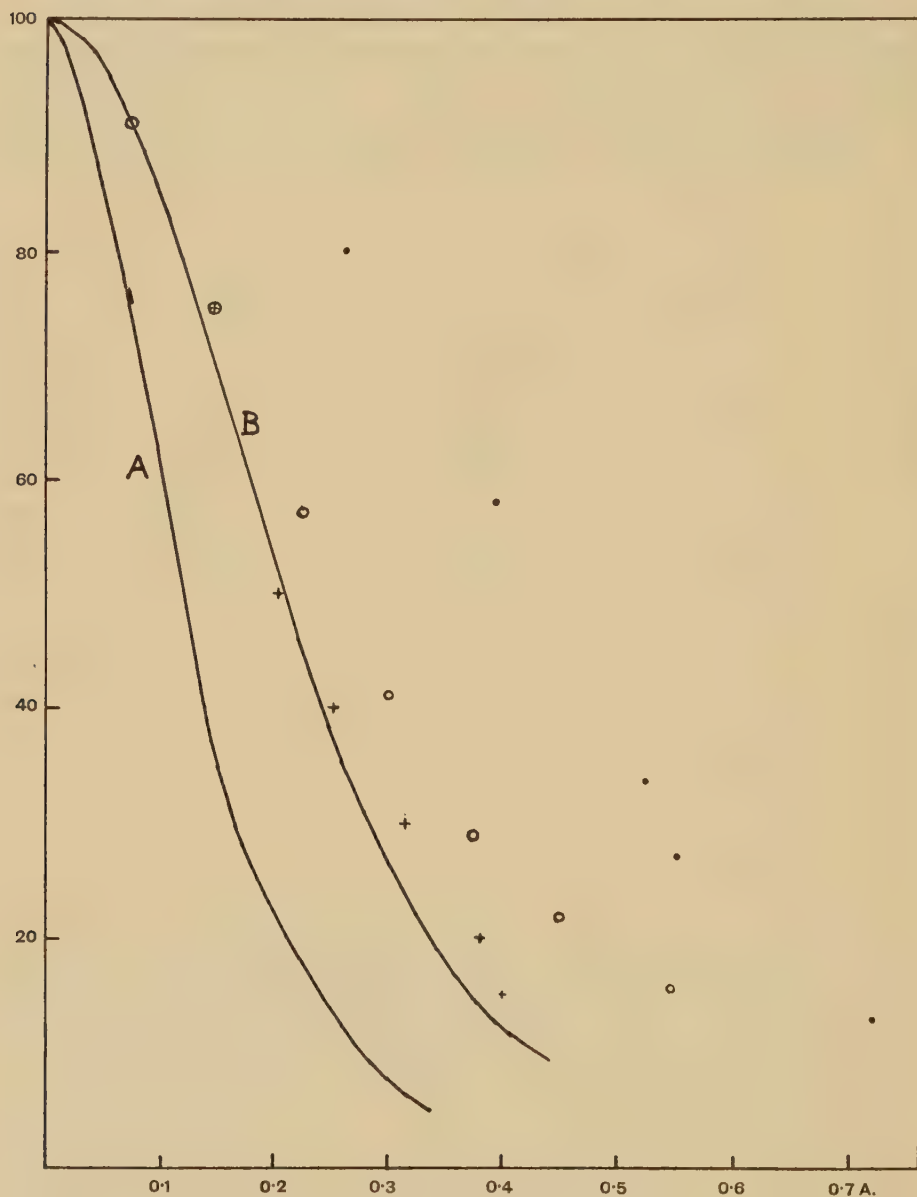


FIG. 4.—Contours of chromospheric lines.

A, Instrumental contour.

B, Contour of line, width *A*, distorted by instrumental contour.

+ Ti^+ , Fe^+ lines at 4500. $\circ$ He 4471. $\bullet$ $H\gamma$ 4340.

the central intensity) of the Ti^+ and Fe^+ lines is 0.46 Å. The instrumental contour of the spectrograph has been recently determined with a krypton tube set up in the laboratory and is shown as curve *A*, with a half-width

of 0.24 Å. (It is doubtful whether the definition at the eclipse was as good as this; the measured linear widths of the *Mg* triplet and *Fe*⁺ 5169 were slightly greater than those at 4500 Å. in spite of the fact that the dispersion was diminished by a factor of nearly two; this suggests strongly that the observed widths are mainly instrumental.) An emission line with true contour A would be distorted by the instrument into the curve B, which fits closely the observed points for *Fe*⁺ and *Ti*⁺. We can therefore safely conclude that the half-widths of these lines do not exceed 0.24 Å. and are probably less. The only lines sufficiently broad to be beyond the effects of finite resolving power are the hydrogen lines, and these are so palpably affected by self-reversal that one cannot interpret them in terms of turbulent velocities without a detailed theoretical investigation of this complicated problem. It would appear that if a further attack on widths of chromospheric lines is contemplated at future eclipses, higher resolving power is greatly desirable, and in any case equipment such as a krypton tube for determining the instrumental contour *in situ* should be regarded as essential as a photometric standardisation.

Summary

The spectrum of the extreme limb of the Sun represents a delicate balance between the emission of the chromosphere and the normal Fraunhofer absorption. The first group of lines to disappear includes hydrogen, ionised metals and rare-earths, *Ti*⁺ slightly later than *Fe*⁺; resonance lines of *Ca*⁺, *Sr*⁺, *Ba*⁺, *Sc*⁺ show emission early with central absorption, usually slightly asymmetrical. Molecular lines follow next. At 0".5 of arc within the limb neutral metals still give an absorption spectrum very similar to that of the disc, but weakened by a factor varying from 1 to 6, the strongest lines being weakened most. A few peculiarities include emission of the *Mg* triplet simultaneously with absorption of subordinate lines of higher E.P.

Emission lines of neutral metals show an unexplained displacement to the violet relative to the limb absorption amounting to a mean value of 0.021 ± 0.010 Å. for 24 lines; allowance is made for instrumental curvature of the lines; the result suggests that the emission lines do not share the well-known red shift in the limb spectrum.

The gradient of intensities in the low chromosphere is much smaller than the theoretical value.

The half-widths of chromospheric *Ti* and *Fe* lines at 4500 Å. cannot be greater than 0.24 Å.

In conclusion the writer wishes to acknowledge his debt of thanks to Dr. Redman for the interest and pleasure provided by the work on his excellent film. Dr. Redman has also offered very helpful advice on some points in the course of the work.

*Solar Physics Observatory,
Cambridge :
1937 August 2.*

SOLAR WAVE-LENGTH DISPLACEMENTS OBSERVED AT THE JAPAN ECLIPSE OF 1936 JUNE 19.

T. Royds, D.Sc., Director, Kodaikanal Observatory.

The spectrum from the limb of the Sun cannot be obtained free from admixture of general sunlight except when, in the course of a total or partial eclipse, light from all parts of the Sun other than the extreme limb is cut off by the Moon. Evershed has found* that in observations made in full sunlight the weak iron lines have a smaller limb shift than the strong lines, and considers that eclipse spectra might show complete equality among all intensity groups. For the purpose of testing this point the Government of India sent me on deputation to join the expedition of the Joint Permanent Eclipse Committee to Japan to observe the wave-lengths of sunlight during the eclipse of 1936 June 19 with the large grating spectrograph of the Kodaikanal Observatory.

The spectrograph consisted of a Rowland plane grating with a collimator of 7 feet focus, and a camera lens of $13\frac{1}{2}$ feet focus with its axis at about 60° to the axis of collimation. The dispersion amounted to 0.73 Å. per mm. in the third order blue region. The image of the Sun, 28 mm. in diameter, was projected on the slit by an 8-inch object-glass of $9\frac{1}{2}$ feet focus. It was originally intended to use an image rotator to turn the Sun's image so that the limb at the points of contact before and after totality would be parallel to the slit, but the rotator was found to introduce considerable astigmatism. The rotator was therefore discarded, and observations were made along a solar diameter from the E. point to the W., with the result that the slit was not parallel to the limb at the points of contact: the slit was vertical and the E. and W. line made an angle of 41° to the horizontal.

The iron arc standards were obtained from a Pfund arc operating at 5 amperes. The arc was photographed simultaneously with the Sun by using two small right-angled prisms in front of the slit to reflect the arc light above and below the Sun's spectrum. These prisms could be independently adjusted so that the beams of light from the arc fell centrally on the collimating lens. This adjustment was verified immediately before the eclipse, and found correct immediately afterwards. At the centre of the Sun's disc the requisite exposure was 5 seconds for the solar spectrum and 20 seconds for the arc.

The guiding of the Sun's image was controlled by watching the image on a prepared slit screen on which had been inscribed circles fitting the Sun's image for different positions along the E.-W. line.

Although the effect sought after was not expected to affect wave-lengths except near the limb of the Sun, a programme of observations was prepared before the eclipse for photographing the Sun's spectrum as close as possible to the Moon's limb at various positions between the centre of the Sun's

* J. Evershed, *M.N.*, 91, 260, 1931.

disc and the limb. It was originally intended to compare the eclipse plates with plates taken before or after the eclipse for each position on the Sun where a photograph had been obtained at the eclipse, but the weather conditions did not permit this to be done.

During the partial phase before totality the programme was carried through almost completely and with clear sky in most cases, but two exposures in the programme could not be made on account of thick cloud. Just at the commencement of totality (which was expected at 6^h 21^m 58^s) the Sun became completely covered by clouds, which remained until the partial phase after totality was so far advanced that the first photograph after totality was at 0.80 radii from the centre. Thereafter the sky was clear, and the prepared programme was departed from in order to obtain as many photographs as possible.

The definition in the eclipse spectra is very good in all photographs, except in the last two taken at the centre of the Sun's disc in which all the arc lines are not sharp for some unknown reason. In all, six plates were exposed, there being space for five exposures on each. Particulars of the exposures and of the measures of the displacements are given below in Table I. Since the scattering effect which is sought after may be expected to depend on the intensity of solar lines, it will suffice here to group the lines according to their intensity. Eleven *Fe* lines measurable on most plates were divided into three intensity groups as below.

Group I	Group II	Group III
Mean intensity 5.2	Mean intensity 3.0	Mean intensity 11.0
4375.946 (6)	4430.624 (3)	4383.559 (15)
4427.319 (5)	4443.205 (3)	4404.763 (10)
4442.351 (6)	4454.390 (3)	4415.135 (8)
4464.662 (4)		
4466.564 (5)		

The lines of Groups I and II are usually easy to measure, but the lines of Group III are most easily measured when the Sun's spectrum is over-exposed.

Considering first the displacements of the lines of Group I, we see the results in Table I where the third column contains the actual displacements in units of 0.0001 Å., after correcting for the Earth's motion by DeLury's tables.* The results from plates A₅ to D₅ have been used to determine the solar rotation which has to be allowed for before arriving at the true solar displacement. The solar rotation was determined by combining the displacements at nearly equal distances from the limb, assuming that the component of rotational velocity in the direction of the Earth was equal to the limb velocity multiplied by the cosine of the angle γ in DeLury's notation. Limb velocities were thus obtained for slightly different latitudes, all near the equator. The mean value for the equatorial solar rotation comes out to be 2.02 km./sec., and this has been used to correct the whole series for the solar rotation, the corrected values being given in the fourth

* DeLury, *Publ. Dom. Obs. Ottawa*, 6, parts 7, 8 and 9.

column of the table. These are the residual solar displacements for Group I. For Groups II and III the residual shifts are given in the fifth and sixth columns.

TABLE I

Sun minus Arc Displacements at Eclipse, expressed in A./10000

Plate	Time U.T.	Distance from Centre in Radii	Sun - Arc corrected for Earth's Motion : Group I	Residual Shifts		
				Group I	Group II	Group III
	h m					
A ₁	5 45	0	+124	+124	+103	+160
A ₂	5 46	0	+113	+113	+81	+83
A ₃	5 56½	·28 E.	+21	+104	+85	+148d†
A ₄	5 57	·28 E.	+15	+98	+91	+68
A ₅	6 04	·57 E.	-12	+151	+135	+98
B ₁	6 06	·57 E.	-47	+116	+78	+126
B ₂	6 11	·76 E.	-46	+178	+139	+220
B ₃	6 12½	·76 E.	-106	+118	+53	+135
C ₁	6 18½	·90 E.	-129	+137	+88	+84d†
C ₂	6 19	·95 E.	-106	+175	+157	+170
C ₃	6 20	·97 E.	-140	+145	+130	+103
C ₄	6 20½	·98 E.	-129	+160	+89	+70d†
C ₅	6 21½	·99 E.	n.m.*	...	...	...
D ₁	6 35½	·80 W.	+385	+149	+132	+155
D ₂	6 36	·66 W.	+342	+147	+102	+131
D ₃	6 37	·61 W.	+318	+138	+98	+105d†
D ₄	6 38	·57 W.	+305	+141	+106	+89
D ₅	6 39	·57 W.	+287	+123	+85	+140
E ₁	6 40½	·47 W.	+222	+82	+49	+69
E ₂	6 42½	·47 W.	+217	+78	+46	+44d†
E ₃	6 43½	·43 W.	+194	+67	+19	+33
E ₄	6 45½	·38 W.	+186	+73	+43	+48
E ₅	6 46½	·33 W.	+181	+83	+43	+75d†
F ₁	6 48½	·28 W.	+158	+75	+47	+82
F ₂	6 49½	·24 W.	+135	+64	+5	+37d†
F ₃	6 50½	·24 W.	+164	+93	+78	+85

* n.m. = not measurable owing to faintness.

† d = difficult to measure.

The values of the limb shift from limb spectra free from the effects of light scattered from the whole Sun have been averaged from the plates C₁ to C₄. The values for the centre of the Sun's disc have been averaged from plates A₁ to A₄ and E₁ to F₃; whether some allowance is made for the change in the displacement (relative to the centre of the disc) for the different distances from the centre at which these plates were obtained, or not, only makes a difference of a few units.

The values for the displacements without an eclipse are taken from

those of Evershed and Royds,* and from new determinations from photographs taken at Kodaikanal in January 1937. The means have been taken for comparison with the eclipse spectra. The results are given below in Table II.

TABLE II
Sun minus Arc Displacements

	Centre of Disc		Limb	
	Without Eclipse	Eclipse	Without Eclipse	Eclipse
Group I	0.0084 A.	0.0088 A.	0.0148 A.	0.0151 A.
Group II	0.0050	0.0058	0.0122	0.0116
Group III	0.0100	0.0078	0.0122	0.0121

Conclusion.—We see in Table II the summary of displacements at the centre of the Sun’s disc and near the limb both with and without eclipse. Both at the centre and at the limb there is no significant difference in the eclipse spectra from those taken in full sunlight. The differential shift between different intensity groups is maintained in eclipse spectra, showing that the effect of scattering in full sunlight does not appreciably affect the wave-lengths of lines as weak as intensity 3 up to points 0.98 radii from the centre of the Sun. Hence the results show that the differences observed in full sunlight in the limb shifts of different intensity groups are not due to scattering of general sunlight into the limb spectrum, but must be taken to be real, and consequently that the relativity theory, or any other theory requiring a general displacement of solar wave-lengths, is not adequate to furnish a complete explanation of solar displacements.

I wish to acknowledge the able assistance of Professor G. H. Marsden, Principal of the Scott Christian College, Travencore, in manipulating the arc lamp for the eclipse observations.

* Evershed and Royds, *Kodaikanal Observatory Bulletin*, No. 39, 1914.

NOTE ON AN ANNUAL CHANGE IN LONGITUDES.

Frank Schlesinger.

In Volume 95 of the *Monthly Notices*, page 452, A. L. Loomis and H. T. Stetson have shown from a study of radio signals that there are changes in longitude between Washington on the one hand and Greenwich and Paris on the other; and that these changes seem to be correlated with the hour-angle of the Moon. In order to bring this out they divided their material into three groups, in the first of which the Moon is north of $+12^\circ$ declination, in the second between $+12^\circ$ and -12° , and in the third south of -12° . The effect is reversed between the first and the third groups and is not present in the second. In Volume 96 of the *Monthly Notices*, page 818, S. Kawasaki has shown that these changes in longitude can be equally well represented by an annual term, wholly independent of the position of the Moon; in this analysis the whole of the material can be treated as a unit.

In both investigations all the curves showing changes in longitude may, as a first approximation, be regarded as sine curves. I have made six least-squares solutions on this basis, the observation equations being of the form

$$C + A \cdot \sin t + B \cdot \cos t = d,$$

d being defined as on page 452 of Loomis and Stetson's paper. The results are:

	A	B	C	Semi- Amplitude
	^s	^s	^s	^s
Greenwich-Washington (Moon north) .	-0016	+0243	+0100	0244
Greenwich-Washington (Moon south) .	+0008	-0200	-0030	0200
Greenwich-Washington (annual) .	0000	+0300	-0008	0300
Paris-Washington (Moon north) .	+0014	+0125	+0222	0126
Paris-Washington (Moon south) .	-0026	-0151	+0150	0153
Paris-Washington (annual) .	+0050	+0235	+0208	0240

We see that on the lunar hypothesis the mean semi-amplitude is $0^s.0180$, and on the annual $0^s.0270$. It is easy to show that when in a sine curve we gather into successive normal points observations that cover a range of phase-angle equal to 2θ , these normal points will fall upon a similar sine curve with the semi-amplitude reduced in the ratio $\sin \theta$ to θ . If in the present case the annual hypothesis is the correct one, then Loomis and Stetson have gathered into one of their points observations that cover 9 hours since that is the range in right ascension of the Moon (for the three years that this investigation covers) during which it remains north of $+12^\circ$ or south of -12° . Consequently θ is here $67^\circ.5$ and the semi-amplitude is reduced by the factor 0.78 ; this is not so far from 0.67 which we deduced from the actual curves.

While this may be regarded as evidence in favour of the annual hypothesis as against the lunar, it can of course not be taken as proof positive. If the phenomenon is lunar there may still be some smoothing in the way in which Loomis and Stetson have collected their data, but how much this may be we cannot estimate until we know how to express the effect as a function of the Moon's declination. It is to be noted that the mean semi-amplitude of the lunar curves is practically the same whether the Moon is far north or far south, $^s.0184$ against $^s.0176$, although these two averages correspond to a change of about 35° in the mean zenith distance of the Moon at all three stations concerned. It is not easy to explain this on the lunar hypothesis. On the annual hypothesis this fact and the reversal in sign for the moon far south as compared with far north have, as Kawasaki has shown, a simple explanation.

Attention is thus directed to seeking possible causes for an annual change in longitude. The wanderings of the earth's pole of rotation with respect to a fixed axis in the earth give rise not only to variations in latitude but to two other effects of the same order of magnitude: variations in azimuth and variations in longitude. That the first of these can be well observed at stations having stable azimuth marks has been proved at the Cape Observatory, at Washington, and elsewhere. Let X and Y , expressed in seconds of arc, define the position of the pole at any time with respect to its mean position. The axis of X is assumed to be directed toward Greenwich, and the axis of Y 90° to the west, that is, toward the American continent. For a station in longitude λ and latitude ϕ , the longitude is then increased by

$$Y \sec \phi_0 + (X \sin \lambda - Y \cos \lambda) \sec \phi, \quad (1)$$

where ϕ_0 is the latitude of Greenwich, $+51^\circ.5$. For Washington λ is $+77^\circ.1$ and ϕ is $+38^\circ.9$. Substituting these we obtain

$$\Delta\lambda = +1.25X + 1.32Y. \quad (2)$$

The period covered by Loomis and Stetson's investigation is 1929.0 to 1932.0. For 1929 and 1930 preliminary values of X and Y are published by Dr. Kimura in the *Japanese Journal of Astronomy and Geophysics*, 8, 14, and 9, 18. For 1931 the values of X as observed at Greenwich are given in the *Monthly Notices*, 92, 456; to conform to our definitions it is necessary to change the signs; and I have added $+0''.05$ to refer them to approximately the same origin. For the Y co-ordinates for 1931 I have used the variations

Mean Co-ordinates of the Pole, 1929.0 to 1932.0

Fraction of Year	X	Y	Fraction of Year	X	Y
0.0	$-.09$	$-.04$	0.5	$+.10$	$+.08$
0.1	$-.14$	$+.02$	0.6	$+.14$	$.00$
0.2	$-.12$	$+.09$	0.7	$+.14$	$-.06$
0.3	$-.06$	$+.13$	0.8	$+.04$	$-.10$
0.4	$+.02$	$+.14$	0.9	$-.03$	$-.11$

observed at Washington (*Astronomical Journal*, 42, 11) appropriately modifying them to allow for the fact that Washington is 13° east of the Y -axis, and adding $+0''.07$ to refer them about to the same origin as in 1929 and 1930. A plot of the variations for all three years was then made, and the means taken for each tenth of the year as shown in the table on p. 697; thus the figure for X at 0.0 is the mean of the three values of X at 1929.0, 1930.0 and 1931.0; and similarly for the other dates and for Y .

Inserting these in formula (2) we get the numbers in the second column of the following table, expressed in seconds of time. The third and the fourth columns are taken from Kawasaki's paper.

Fraction of Year	$\Delta\lambda$ Computed	$\Delta\lambda$, observed	
		Greenwich	Paris
	^s	^s	^s
0.0	- 0.11	- 0.25	- 0.29
0.1	- 10	- 22	- 21
0.2	- 2	- 12	- 1
0.3	+ 7	- 2	+ 9
0.4	+ 14	+ 27	+ 13
0.5	+ 15	+ 34	+ 15
0.6	+ 12	+ 26	+ 12
0.7	+ 7	+ 9	+ 10
0.8	- 5	- 10	+ 3
0.9	- 12	- 24	- 12

The computed differences of longitude agree as well as we should expect with those observed between Paris and Washington, but those between Greenwich and Washington are considerably larger. We see then that the polar motion is at least a partial explanation of the effect unearthed by Loomis and Stetson and by Kawasaki. It may well be that it is a complete explanation; our column (2) in the table agrees much better with the Paris data than the latter do with Greenwich, the sum of the squares of the ten differences in the two cases being 0.0526 and 0.1326. Until the large differences between Paris and Greenwich, separated by only 330 km., are cleared up, we can by no means be sure that the polar motion will not account for the Greenwich-Washington changes in longitude as well as the Paris-Washington changes.

If the work of Loomis and Stetson is to be extended to years preceding or following their interval, it will be well to treat each year by itself and not to combine it with other years. Ordinarily the 14-month term in the polar motion would mask some of the effect of the annual term if several years are combined. In the present case, however, covering 1929.0 to 1932.0, it happens that the annual term predominates and the differences of longitude come out as an annual term. But in general the latter will show the same periods as the polar motion.

It is clear that in the light of Kawasaki's paper and this one, the correlations between the latitude and the Moon's position ought now be re-examined.

Yale University Observatory :

1937 June 1.

ON THE INFLUENCE OF THE CONCENTRATION OF ENERGY SOURCE ON THE CHARACTER OF STELLAR CONFIGURATION.

A. B. Severny.

1. In this paper we consider a special model of a star with the law of the energy source concentration towards the centre

$$\eta \equiv \frac{L(r)}{M(r)} \propto T^l, \quad (l > 0). \quad (1.1)$$

This model has been already considered by Jeans* in 1925 and recently by Chandrasekhar.† Our problem is to examine the sequence of the configurations with the law (1.1) when l varies from 0 to ∞ , under the following assumptions:—

(1) The law of opacity is

$$\kappa = \kappa_0 \rho T^{-7/2}. \quad (1.2)$$

(2) The material of the star is perfect gas with the equation of state

$$p_G = \frac{R}{\mu} \rho T. \quad (1.3)$$

(3) The radiation within the star is isotropic so that

$$p_R = \frac{1}{3} a T^4. \quad (1.4)$$

We have no special reasons for assuming the law (1.1), but it enables us roughly to characterize the energy source concentration towards the centre; and furthermore, the model with the law (1.1), according to Chandrasekhar,† is connected with the problem of the negative density

gradients in stars. Put $\frac{L(r)}{M(r)} = \eta_0 T^l$. Let η_0 be determined by the condition that at a certain $T = T_0$, $\frac{L(r)}{M(r)} = \frac{L}{M}$, so that $\eta_0 = \frac{L}{M} T_0^{-l}$; we shall not specify the value of T_0 . Now the fundamental equations of the problem are

$$\frac{d}{dr}(p_G + p_R) = -\frac{GM(r)}{r^2} \rho, \quad \frac{dp_R}{dr} = -\frac{\kappa_0 \rho T^{-7/2}}{4\pi c r^2} M(r) \eta_0 \rho T^l. \quad (1.5)$$

When $l = \frac{1}{2}$ we have Eddington's model where $p_G \propto p_R$, $\kappa \eta = \text{const}$. The case $l = 0$ corresponds to uniform energy source distribution, ‡ and the case $l = 4.5$ has been examined recently by Chandrasekhar.

* M.N., 85, 196, 1925.

† M.N., 97, 132, 1936.

‡ Jeans, *loc. cit.*; *Astron. and Cosm.*, p. 85, 1928; also Biermann, *Zs. f. Ap.*, 3, 116, 1931.

Introducing the new variables

$$x = K p_R^\epsilon, \quad \lambda = p_G / p_R \quad (1.6)$$

with

$$K = \frac{4\pi c G M}{\kappa_0 L} \frac{R/\mu}{\frac{1}{3}a} T_0^{1/3} \left(\frac{1}{3}a\right)^{-\epsilon}, \quad \epsilon = \frac{1}{4}\left(\frac{1}{2} - l\right),$$

from (1.5) we get the equation determining the first integral of the problem (the dependence ρ on T) *

$$\epsilon x \lambda \frac{d\lambda}{dx} = x - \lambda(\lambda + 1). \quad (1.7)$$

We shall not examine the integral curves of (1.7) for the cases $\epsilon \geq 0$ as the behaviour of these curves has been considered by Jeans (for $\epsilon > 0$) and by Chandrasekhar (for $\epsilon = -1$), and we refer the reader to the papers cited above.† In the case $\epsilon < 0$, x decreases with T , and we introduce in place of x

$$z = \frac{1}{x} = p_R^a / K, \quad a = -\epsilon > 0. \quad (1.8)$$

Then (1.7) becomes

$$a z^2 \lambda \frac{d\lambda}{dz} = 1 - z \lambda (\lambda + 1). \quad (1.9)$$

2. Consideration of the solutions of (1.7) and (1.9) shows that these may be divided into categories: (a) The solutions for which in some, if not in every interval of the variation of T , λ decreases with increasing T ; and (b) the solutions for which λ decreases nowhere with increasing T . If for a given configuration λ decreases with increasing T , i.e. ρ/T^3 decreases with increasing T , then T increases inwards more rapidly than $\rho^{1/3}$ and the total pressure increases more rapidly than $\rho^{4/3}$, say as $\rho^{4/3+q}$, ($q > 0$). Thus the parameter of the “*osculierende politrope*” is $\gamma_R = \frac{4}{3} + q$, but according to Siedentopf's‡ investigation for $\gamma_R > \frac{4}{3}$, convection within the star may in general appear. When λ increases with increasing T , then $\gamma_R < \frac{4}{3}$, and convection, generally speaking, may not appear.

However, for the strict consideration of the occurrence of convection for the model under discussion we shall use the very important criterion introduced by Chandrasekhar (*loc. cit.*, p. 135): if the temperature T increases inwards, $\frac{d\rho}{dT}$ will be positive or negative according as

$$x \gtrless \lambda \left(1 + \frac{1}{4}\lambda\right) \quad (2.1)$$

respectively, i.e. for all the points below the *parabola*

$$x = \lambda \left(1 + \frac{1}{4}\lambda\right), \quad (2.2)$$

* See, for instance, Jeans, *loc. cit.*; Chandrasekhar, *loc. cit.*, p. 134.

† Equation (1.7) has two singular points: (0, 0) and (0, -1); the detailed qualitative investigation of (1.7) has been carried out (for $\epsilon \geq 0$) by the author (*Russ. Astr. Journ.*, in press).

‡ *A.N.*, 244, 276, 1932.

$\frac{d\rho}{dT} > 0$ (or $\frac{d\rho}{dr} < 0$), while for all the points above (2.2) $\frac{d\rho}{dT} < 0$ (or $\frac{d\rho}{dr} > 0$).

For the case $\epsilon < 0$ in the λ, z plane, the locus $\frac{d\rho}{dT} = 0$ is

$$\frac{1}{z} = \lambda(1 + \frac{1}{4}\lambda). \quad (2.3)$$

For all the region of the λ, x (or λ, z) plane above (2.2) (or (2.3)) the adiabatic temperature gradient $-\left(\frac{dT}{dr}\right)_A = -(\gamma_A - 1) \frac{T}{\rho} \frac{d\rho}{dr}$ is smaller than the actual temperature gradient $-\left(\frac{dT}{dr}\right)_R$ (with r increasing inwards), therefore in this region convection currents will exist.* Thus convection may exist in the model examined if the integral curve (corresponding to the given initial conditions) of (1.7) (or (1.9)) lies entirely or partly in the region $\frac{d\rho}{dT} < 0$. In the second case the integral curve has to cross the curve (2.2) (or (2.3)). But in crossing this curve $\frac{d\rho}{dT} = 0$ an integral curve may enter the region $\frac{d\rho}{dT} > 0$, or emerge from this region. If an integral curve enters the region $\frac{d\rho}{dT} > 0$, then it ought to tell us something about convection in the external layers of the star, while in the second case we should get information about convection in the interior (see below).

3. Let us consider the behaviour of the integral curves of (1.8) with respect to the locus $\frac{d\rho}{dT} = 0$ in the cases $\epsilon \gtrless 0$.† Introduce now the one-parameter family

$$f(x, \lambda) \equiv \frac{1}{x} \lambda(1 + \frac{1}{4}\lambda) = C \quad (3.1)$$

(so that C is a positive single-valued and continuous function of the point (x, λ)) and consider the system equivalent to (1.7), namely, the system

$$\left. \begin{aligned} \frac{d\lambda}{dt} &= x - \lambda(1 + \lambda), \\ \frac{dx}{dt} &= \epsilon x \lambda. \end{aligned} \right\} \quad (3.2)$$

* Of course, convective instability may occur also with $\frac{d\rho}{dT} > 0$, but in this paper we shall deal only with this necessary condition. (Cf. Cowling, *M.N.*, 94, 768, 1934.)

† The author is indebted to Prof. N. D. Moisseiev, who suggested to him the method of the contact characteristics developed by him and Hadamard (see Moisseiev, *Publ. of the Sternberg State Astr. Inst.*, 8, part 1, 1936).

The derivative

$$\frac{dC}{dt} = \frac{\partial f}{\partial x} \frac{dx}{dt} + \frac{\partial f}{\partial \lambda} \frac{d\lambda}{dt} = -\frac{1}{x^2} \lambda \left(1 + \frac{1}{4} \lambda\right) \dot{x} + \frac{1}{x} \left(1 + \frac{1}{2} \lambda\right) \dot{\lambda} \quad (3.3)$$

in virtue of (3.2) will be

$$\frac{dC}{dt} = -\frac{1}{x} \left(1 + \frac{1}{4} \lambda\right) \epsilon \lambda^2 + \frac{1}{x} \left(1 + \frac{1}{2} \lambda\right) (x - \lambda(1 + \lambda)). \quad (3.4)$$

At points of the curve (2.2) we have

$$\frac{dC}{dt} = -\frac{\lambda^2}{x} \left\{ \frac{\lambda}{4} \left(\frac{3}{2} + \epsilon\right) + \left(\frac{3}{4} + \epsilon\right) \right\}, \quad (3.5)$$

whence it follows that at $\epsilon > 0$, $\frac{dC}{dt} < 0$ for any point of the parabola (2.2); consequently at $\epsilon > 0$ the integral curves of (1.7) always enter the region $\frac{d\rho}{dT} > 0$. Putting $\epsilon = -a$ for the case $\epsilon < 0$ we find that the point

$$\lambda' = 4 \frac{a - \frac{3}{4}}{\frac{3}{2} - a}, \quad x' = \frac{1}{z'} = 3 \frac{a - \frac{3}{4}}{(a - \frac{3}{2})^2} \quad (3.6)$$

of the curve (2.2) (or (2.3)) will be the point of contact $\left(\frac{dC}{dt} = 0\right)$ of an integral curve of the family of (1.9) with the locus $\frac{d\rho}{dT} = 0$. Further, at $\epsilon < 0$

$$\frac{dC}{dt} = -\frac{\lambda^2}{4x} \left(\frac{3}{2} - a\right) (\lambda - \lambda'), \quad (3.7)$$

thus from (3.6) and (3.7) it follows:—

(1) At $a \leq \frac{3}{4}$ all the integral curves always enter the region $\frac{d\rho}{dT} > 0$ (similarly to the case $\epsilon > 0$);

(2) For $\infty > a \geq \frac{3}{2}$ all the integral curves always emerge outside the region $\frac{d\rho}{dT} > 0$; and

(3) In the case $\frac{3}{2} > a > \frac{3}{4}$ the integral curves always enter the region $\frac{d\rho}{dT} > 0$ when $\lambda > \lambda'$ (or $z < z'$) and always emerge outside this region when $\lambda < \lambda'$ (or $z > z'$).

Now, when l of (1.1) varies from 0 to ∞ (consequently ϵ from $\frac{1}{8}$ to $-\infty$) the character of the examined configurations will be changed as follows:—

(1) When $0 \leq l \leq 3.5$ convection may first appear only in the external layers of the star, so that if in these layers $\frac{d\rho}{dT} > 0$, then $\frac{d\rho}{dT}$ must be positive throughout the star; (2) when $3.5 < l < 6.5$ convection may appear (with the corresponding conditions) both in the interior and in the outer layers; and (3) in the case $6.5 \leq l < \infty$ the configuration may be convective only

in the interior.* These conclusions are valid only for such configurations for which the integral curve of (1.7) crosses once (at least) the locus $\frac{d\rho}{dT}=0$.

Any of these configurations as a whole may be convective and may be convectively stable for corresponding conditions at the boundary and at the centre of the configuration.

4. It is easy to prove that the curve $\frac{d\rho}{dT}=0$ always passes through the region where $\frac{d\lambda}{dx}$ (or $\frac{d\lambda}{dz}$) is negative. Let us consider closely the case $3.5 < l < 6.5$. When in the interior of the configuration convection is set up, then the integral curve of (1.9) emerges from the region $\frac{d\rho}{dT} > 0$, but this will only be so, provided $\lambda(z_c) < \lambda(z_1) < \lambda'$ (see § 3), where z_c is the value of $z(\propto T^{l-1/2})$ at the centre and z_1 is the root of the equation $\lambda(z_1) + 2(1 - \sqrt{1 + z_1^{-1}}) = 0$ (see (2.3)). Thus convection in this case will always take place if $\beta_c/1 - \beta_c < \lambda'$ (with the usual notation), or

$$1 - \beta_c > \frac{1}{3} \frac{\frac{3}{2} - a}{a - \frac{1}{2}} \equiv 1 - \beta_c^0. \quad (4.1)$$

The critical values of $1 - \beta_c$ are shown in Table I for the different values of l .

TABLE I

l	$1 - \beta_c^0$	l	$1 - \beta_c^0$
3.5	1.00	5.3	0.14
3.7	0.78	5.7	0.08
4.1	0.50	6.1	0.04
4.5	0.33	6.3	0.02
4.9	0.22	6.5	0.00

It is of interest to note that Chandrasekhar has found the following condition for the occurrence of the negative density gradient in the star with $l = 4.5$:—

$$1 - \beta_c > \sim 0.5. \quad (4.2)$$

But in deriving (4.2) he deals only with one of the integrals of (1.7) (called by him “standard solution”), while for other integrals of (1.7) the value of $1 - \beta_c^0$ is smaller than 0.5, as may be seen from his fig. 1. Thus, our conclusion agrees quantitatively with Chandrasekhar’s result. In addition, our conclusion that convection in the interior of the stars is set up only by a sufficiently high concentration of the energy source towards the centre is found to be in accordance with all the investigations on the

* Or, according to Rosseland (*Zs. f. Ap.*, 4, 255, 1932) and Biermann, these configurations will possess a convectively unstable core (see *Zs. f. Ap.*, 4, 61, 1932).

influence of the energy source concentration upon the appearance of convection,* particularly with the very interesting conclusions of Weizsäcker.†

In conclusion, the author wishes to express thanks to Professor Ambarzumian for his helpful remarks connected with this paper.

*The Physical Mathematical
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1937 June.*

THE STELLAR PROBLEM OF THREE BODIES : ADDITION TO PAPER IV.

Ernest W. Brown.

Dr. W. J. Luyten has called my attention to the fact that doubt exists as to whether the angle between the planes of the two orbits is $37^{\circ}.8$ or $142^{\circ}.2$. In Paper IV ‡ I have taken it to be the former, which involves the revolutions of the two bodies in the same sense. Simple changes in the results obtained can be made for application to the latter case when one body is revolving in a direction which is retrograde with respect to that of the other.

If the mean anomaly f' of the outer body be reckoned in the same sense as the motion of that body, then all the long-period perturbations—that is, those depending on multiples of f' —will have their signs changed.

The “apse-node” variations in the elements are, to the order of approximation obtained in the paper, found by changing the signs of the portions depending on k_2 . Thus the mean motion of the periastron which was

$$(\cdot 00103 + \cdot 00148)n'$$

becomes

$$(\cdot 00103 - \cdot 00148)n' = -\cdot 0045n',$$

the latter of the two portions being approximately that dependent on k_2 . The periastron, therefore, regresses as might have been expected. The motion of the node is but little affected. The results obtained in this way give the order of magnitude of the variations. Properly, the work should be carried through as before with the sign of k_2 changed.

* See, for instance, B. Strömgen, *Handb. d. Aph.*, Bd. VII (Ergänzungsband).

† *Phys. Zs.*, 38, Nr. 6, 1937.

‡ *M.N.*, 97, 388, 1937.

OCCULTATIONS OF STARS BY THE MOON, OBSERVED AT
THE ENGELHARDT OBSERVATORY, KASAN, IN 1936,
AND THE REDUCTION OF THE OBSERVATIONS MADE
DURING 1932-1935.

(Communicated by the Secretaries)

The reductions were made by I. W. Belkovitsch.

Table I gives the observed times with the corresponding remarks.
When the same star was observed by two observers the arithmetical mean
of the times was taken, provided their divergence was not great.

Table II gives the reductions.

Before taking the co-ordinates of the Moon from the *Nautical Almanac*
a correction of +0^h.00152 was applied to the observed times.

TABLE I

No.	Date	U.T.	Star	Mag.	Phase	Instru- ment and Power	Ob- server	Remarks
1	1936 Mar. 26	^h ^m ^s 16 57 6.7	B.D. +21° 473	9.0	D	M 56	M	Very un- certain
2	26	16 58 29.8	B.D. +21° 474	8.6	D	M 56 R 143	M B	
3	28	17 35 27.6	121 Tauri	5.3	D	H 132 M 56	B A	
4	29	18 39 23.0	B.D. +22° 1397	9.0	D	M 56	M	Uncertain
5	June 2	19 10 43.1	18 G Libr	6.1	D	H 132	B	Very un- certain
6	2	19 10 37.3	"	"	"	M 56	A	Certain
7	Sept. 25	18 28 45.0	f Sag	5.1	D	R 143 H 132	N B	
8	26	15 24 45.9	47 B Cap	6.2	D	M 56 H 132	A B	

Observers :

A = Mrs. L. D. Agafonova.
B = I. W. Belkovitsch.
M = D. J. Martinoff.
N = Miss S. V. Nekrasova.

Instruments used :

H = Heliometer (106 mm.).
M = Refractor (150 mm.).
R = Refractor (306 mm.).

TABLE II

No.	χ	ρ	$\sigma' - \sigma$
	$^{\circ}$ $'$	$^{\circ}$ $'$	$''$
1	124 9	81 4	+3.8
2	119 9	81 4	+1.5
3	78 58	92 6	-0.7
4	94 34	99 39	+3.7
5	143 36	104 5	+0.5
6	143 36	104 5	+2.3
7	67 26	75 30	-1.8
8	88 56	71 56	-0.8

The positions of the stars B.D. +21° 473, B.D. +21° 474 and B.D. +22° 1397 were taken from *Ann. Obs. Belg.*, t. xiii. The corrections for proper motion were applied only in regard to the star B.D. +21° 473 according to the *Eigenbewegungs-Lexikon*.

The apparent places of these stars for the date of observation are as follows :—

TABLE III

Star	α	δ
	$^{\text{h}}$ $^{\text{m}}$ $^{\text{s}}$	$^{\circ}$ $'$ $''$
B.D. +21° 473	3 27 39.11	+21 35 4.6
B.D. +21° 474	3 27 45.54	+21 36 24.0
B.D. +22° 1397	6 32 2.60	+22 38 57.8

The positions of the other stars are taken from the *Nautical Almanac*.

Below are given the reductions of the occultations observed at the Engelhardt Observatory, 1932–1935, kindly communicated by G. B. Agavonof.

Before taking the co-ordinates of the Moon from the *Nautical Almanac* the following corrections were applied to the observed times : during 1932, +0^h.00303 ; during 1934–1935, +0^h.00253.

The apparent positions of the stars for observations 10–12 and 13–14 in 1934 were taken from the *Anuario Observ. Astr. de Tacubaya*, 1934.

The observed time No. 16 in 1935 must be diminished by 5^m of sidereal time.

The times Nos. 16–19 in 1936 should be diminished by 10^s.

The observation No. 5 in 1935 should be excluded because its reduction does not give any satisfactory result.

TABLE IV

Vol. and Page of the <i>M.N.</i>	No. of Occult. in the <i>M.N.</i>	λ	ρ	$\sigma' - \sigma$	Year
94, 876	100	⁰ 51 49	⁰ 85 6	" -1.4	1932
"	101	51 48	85 6	-1.7	"
96, 554	1	67 10	77 51	-4.1	1934
"	2	108 8	77 51	-3.3	"
"	3	53 25	78 5	-0.8	"
"	4	10 58	78 5	-0.7	"
"	5	138 48	114 14	+0.8	"
"	6	156 38	114 14	-2.5	"
"	7	156 37	114 14	-2.2	"
"	8	2 41	79 8	-1.1	"
"	9	2 47	79 8	-0.6	"
"	10, 11	53 46	79 8	-2.7	"
"	12	53 46	79 8	-3.3	"
"	13, 15	33 20	79 8	-2.5	"
"	14	33 22	79 8	-1.9	"
"	16	109 16	108 45	-3.3	"
96, 901	1	91 26	79 8	-0.7	1935
"	2	51 20	79 22	-2.7	"
"	3, 4	42 42	79 21	-1.9	"
"	6, 7	119 25	79 37	-1.1	"
"	8	160 56	79 52	-0.7	"
"	9, 10	62 29	66 27	-2.4	"
"	11	52 55	80 25	-2.0	"
"	12, 15	99 3	64 47	-0.6	"
"	13	99 2	64 47	-0.2	"
"	14	99 5	64 47	-1.1	"
"	16, 17	37 57	64 53	-2.2	"
"	18, 19	38 58	64 53	-1.8	"

Engelhardt Observatory :
1937 *June.*

OCCULTATIONS OF STARS BY THE MOON, OBSERVED AT THE NIZAMIAH OBSERVATORY, HYDERABAD, DURING THE YEAR 1936.

(Communicated by the Director)

No.	Star	Mag.	Phase	Date	U.T.
				1936	h m s
1	Abbadia 4229	8.1	D	Jan. 8	17 32 53.2
2	δ Geminorum	3.5	D	8	18 7 4.8
3	36 Tauri	5.7	D	Feb. 1	16 22 57.9
4	A.G. Berlin 502	9.8	D	26	13 59 31.6
5	B.D. +15° 259	9.5	D	26	14 4 37.0
6	B.D. +19° 406	9.5	D	27	13 37 34.3
7	Abbadia 1215	8.6	D	27	13 51 36.6
8	B.D. +19° 408	9.5	D	27	13 54 20.1
9	Abbadia 1221	9.2	D	27	14 30 54.7
10	Abbadia 1224	8.0	D	27	14 38 15.1
11	B.D. +22° 560	9.5	D	28	15 54 47.9
12	104 B Tauri	5.5	D	28	16 1 4.0
13	Paris ph. +24° 3 ^h 44 ^m 299	10.5	D	28	16 7 29.3
14	B.D. +23° 555	9.4	D	28	16 12 16.0
15	A.G. Berlin 1199	8.8	D	28	16 27 20.6
16	B.D. +22° 567	9.0	D	28	16 41 57.5
17	Abbadia 1750	7.2	D	28	16 52 49.1
18	B.D. +24° 966	9.4	D	Mar. 1	16 37 29.6
19	B.D. +24° 969	9.1	D	1	16 41 10.0
20	Abbadia 2839	8.5	D	1	16 44 41.0
21	Abbadia 2846	5.3	D	1	16 56 17.2
22	Abbadia 2539	8.7	D	28	14 45 48.6
23	Abbadia 3416	7.5	D	29	14 16 49.4
24	36 B Geminorum	6.0	D	29	14 44 33.6
25	B.D. +23° 1349	9.5	D	29	14 50 8.7
26	Abbadia 3443	8.5	D	29	15 18 53.3
27	64 G Libræ	5.7	R	Apr. 9	20 54 12.6
28	88 B Ophiuchi	5.9	R	11	18 21 4.2
29	26 Ophiuchi	5.8	R	12	18 33 56.9
30	Abbadia 4702	9.0	D	27	14 41 13.8
31	η Virginis	5.4	D	May 3	14 37 28.9
32	Cordoba 12053	8.0	D	Oct. 20	13 42 58.7
33	51 Ophiuchi	4.9	D	20	13 50 15.9
34	d Piscium	5.6	D	Nov. 24	18 32 57.3
35	20 H' Arietis	6.4	D	26	13 24 45.7
36	ζ Arietis	5.0	D	27	14 36 12.5
37	B.D. -6° 5959	9.2	D	Dec. 19	14 32 6.0
38	44 Aquarii	5.8	D	19	14 37 19.9
39	133 B Tauri	5.9	D	25	13 52 45.8
40	1 Geminorum	4.3	D	27	16 53 48.1
41	η Geminorum	3.3	D	27	22 50 6.5
42	η Geminorum	3.3	R	27	23 43 50.0

All the observations were made by M. K. Bappu with the 15-inch Grubb refractor and the times in all cases were noted with a stop-watch. The clock corrections were determined from observations with the transit instrument.

The reductions have been carried out by M. V. V. Sastri and S. Aravamudan. A correction of $0^h.0015$ has been added to the observed time to allow for the error of $3''$ in the mean longitude of the Moon.

No.	χ	ρ	$\sigma' - \sigma$	$\cos(\chi - \rho)$	No.	χ	ρ	$\sigma' - \sigma$	$\cos(\chi - \rho)$
	$^{\circ} \quad '$	$^{\circ} \quad '$	"			$^{\circ} \quad '$	$^{\circ} \quad '$	"	
1	69 35	102 27	+0.7	+0.840	22	75 0	91 25	-0.9	+0.959
2	66 20	102 34	-0.6	+0.807	23	139 24	97 16	+1.2	+0.742
3	131 26	82 44	-0.7	+0.660	24	176 8	97 23	-1.3	+0.195
4	70 27	70 40	-0.8	+1.000	25	149 33	97.24	-1.1	+0.614
5	60 30	70 41	-0.1	+0.984	26	33 57	97 36	+0.8	+0.444
6	61 57	75 8	-1.3	+0.974	27	283 43	101 46	-0.8	-1.000
7	65 40	75 11	+0.3	+0.986	28	236 46	91 50	+1.1	-0.818
8	56 11	75 11	+0.0	+0.946	29	266 52	91 47	+2.0	-0.996
9	64 8	75 19	-0.6	+0.981	30	58 54	105 48	+1.8	+0.683
10	57 2	75 21	+0.5	+0.949	31	130 29	112 55	-0.6	+0.953
11	115 48	81 11	+0.2	+0.823	32	37 46	87 57	-0.2	+0.640
12	107 2	81 13	-0.8	+0.900	33	74 47	87 55	-1.7	+0.974
13	103 53	81 14	-4.0	+0.923	34	359 49	67 46	-0.9	+0.375
14	84 35	81 15	-1.6	+0.998	35	18 10	73 18	-1.4	+0.572
15	110 27	81 19	+2.8	+0.874	36	43 22	78 33	-1.8	+0.817
16	151 4	81 23	-3.7	+0.347	37	58 34	67 8	+1.9	+0.989
17	37 18	81 25	-0.5	+0.718	38	65 0	67 8	-0.4	+0.999
18	69 43	93 34	+1.4	+0.915	39	97 35	81 47	-2.6	+0.962
19	114 42	93 35	-1.2	+0.933	40	31 51	95 4	-1.2	+0.451
20	124 47	93 36	+2.8	+0.856	41	80 10	96 35	-0.9	+0.959
21	113 42	93 39	+0.2	+0.939	42	313 12	96 48	+5.5	-0.805

In the table below are given the mean places (1936.0) of ten stars computed from positions in the "Carte du Ciel" Catalogues for use in the reductions.

No.	Star	Mag.	R.A. 1936.0	Declination 1936.0	Authority
			$^h \quad ^m \quad ^s$	$^{\circ} \quad ' \quad ''$	
5	B.D. +15° 259	9.5	1 42 42.19	+16 0 44.5	Paris ph. +15° 1 ^h 40 ^m 25; +16° 1 ^h 44 ^m 76
6	B.D. +19° 406	9.5	2 40 27.86	+20 18 37.1	Paris ph. +20° 2 ^h 40 ^m 33; +21° 2 ^h 36 ^m 133
8	B.D. +19° 408	9.5	2 40 52.22	+20 21 41.5	Paris ph. +20° 2 ^h 40 ^m 35; +21° 2 ^h 36 ^m 135
11	B.D. +22° 560	9.5	3 44 17.11	+23 11 12.3	Paris ph. +22° 3 ^h 44 ^m 66
14	B.D. +23° 555	9.4	3 44 58.02	+23 19 51.4	Paris ph. +24° 3 ^h 44 ^m 306
16	B.D. +22° 567	9.0	3 45 23.41	+23 4 23.2	Paris ph. +24° 3 ^h 44 ^m 322
18	B.D. +24° 966	9.4	5 44 35.77	+24 46 33.8	Paris ph. +24° 5 ^h 44 ^m 98
19	B.D. +24° 969	9.1	5 44 39.55	+24 34 10.5	Paris ph. +24° 5 ^h 44 ^m 102
25	B.D. +23° 1349	9.5	6 22 18.12	+23 23 19.4	Paris ph. +24° 6 ^h 16 ^m 326
37	B.D. -6° 5959	9.2	22 13 35.09	- 5 42 6.0	San Fernando -5° 22 ^h 12 ^m 90; -6° 22 ^h 8 ^m 186; -6° 22 ^h 16 ^m 1

LIST OF ADDITIONS
TO THE
LIBRARY OF THE SOCIETY

1936 AUGUST 1 TO 1937 JULY 31

Serial Publications received by exchange in the regular course, and Reprints of Papers published in some of these Serials, are not included in this Annual List.

Unless otherwise indicated, the donor is the author or the Institution concerned.

An asterisk () indicates that the work is an excerpt.*

A dagger (†) indicates that the work has been purchased.

Aarhus, Ole Rømer Observatoriet :

Meddelelser, Nos. 6-8.

4to. Aarhus, 1936-37

Aitken (Robert Grant) :

*Driving back the Dark. (Supplement to Bulletin of East Bay Astronomical Association.)

(E. G. Linsley.)

8vo. Northfield (Minn.), 1937

Allen (C. W.) :

*The brightness of the Sky, with special reference to the region within 3° of the Sun.

8vo. Leipzig, 1935

American Institute of Physics :

——: †Journal of the Optical Society of America. Cumulative Index. Volumes 1-25. 1917-1935.

cr. 8vo. New York, 1936

——: See also Optical Society of America.

Association of Special Libraries and Information Bureaux :

Select List of Standard British Scientific and Technical Books. Compiled at the request of the British Council. Foreword by Sir William Bragg, O.M., K.B.E., D.Sc. Introduction by Sir Richard Gregory, Bart., D.Sc., F.R.S.

8vo. London, 1937

Bacher (Robert F.) and Samuel Goudsmit :

†Atomic energy states as derived from the analyses of optical spectra. [International Series in Physics. F. K. Richtmeyer, Consulting Editor.]

8vo. New York and London, 1932

Bellamy (Ethel F.) :

Index Catalogue of Epicentres for 1913-1930. A geographical index to the
International Seismological Summary. 8vo. Newport, I.O.W., 1936

Berlin, Preussische Akademie der Wissenschaften :

†Geschichte des Fixsternhimmels. Abteilung I, Der nördliche Stern-
himmel. Band 24. 4to. Karlsruhe, 1936

Band 24. 23^h Rektaszension.

Berlin-Charlottenburg, Physikalisch-Technische Anstalt:

Wissenschaftliche Abhandlungen. Band 20, Hefte 1-5. 4to. Berlin, 1935-36

†**Bibliographia Kepleriana** : Ein Führer durch das gedruckte Schrifttum
von Johannes Kepler, mit 80 Faksimile. Im Auftrag der Bayerischen
Akademie der Wissenschaften unter Mitarbeit von Ludwig Rothenfelder.
Herausgegeben von Max Caspar. fol. München, 1936

Blackett (P. M. S.) :

†Cosmic Rays, being the Halley Lecture delivered on June 5, 1936.
8vo. Oxford, 1936

Bloch (Olaf F.) :

*Application of Photography to Scientific and Technical Problems.
8vo. London, 1937

British Science Guild, The :

The Norman Lockyer Lecture, 1936. 8vo. London, 1936
The Rt. Hon. Lord Rutherford, "Science in Development."

Brown (Ernest W.) and Dirk Brouwer :

†*Tables for the development of the Disturbing Function, with schedules
for harmonic analysis. 4to. Cambridge, 1933

Brück (Hermann) :

*Über die Verteilung der Sterne verschiedener Spektralklassen.
8vo. Berlin, 1937

Cape Town, Astronomical Society of South Africa :

Journal. Vol. 4, No. 2. 8vo. Cape Town, 1937

Caspar, Max : See *Bibliographia Kepleriana*.

Catania, Reale Osservatorio :

Miscellaneous Papers.

A. Bemporad, *Astronomi poeti. Conferenza tenuta nell'Osservatorio il 23 giugno
1934. 8vo. Catania, 1935

A. Bemporad, E para stella che tramuti loco. Conferenza tenuta nell'Osservatorio
il 6 aprile 1935. 8vo. Roma, 1935

Chatley (Herbert) :

- *T'ai chi Shang Yuan. The Chinese astrological theory of creation.
8vo. *s.l.*, 1936

Collard (Auguste) :

- : *Goethe et Quetelet: leur relations de 1829 à 1832. 8vo. Bruges, 1934
—: *Magister Jacobus Angelus de Ulma et son "Tractatus de cometis."
8vo. Bruxelles, 1935
—: *Bibliographie des Travaux Belges. 1929-1932. 8vo. Bruxelles, *s.d.*

Comrie (L. J.) :

- *Inverse Interpolation and Scientific Applications of the National Accounting Machine.
8vo. London, 1936

Corbu (J.) :

- *Les lois de la rotation solaire. 8vo. Cluj, 1937

Cordoba, Observatorio Nacional Argentino :

- Cordoba Durchmusterung. New edition. Maps 13, 14, 15.

Cox (J. F.) :

- *Notice sur la vie et les travaux de Paul Stroobant. 8vo. Bruxelles, 1936

Crohamhurst Observatory, Queensland :

- : Observatory Paper. Nos. 5, 6. 8vo. Brisbane, 1936
—: Report for the quarters ending 30th June, 30th September, 1936; Report for the year ending 31st December 1936. fol. typescript, 1936-37

da Costa Lôbo (F. M.) :

- *Théorie radiante. Conférence faite à la Sorbonne, . . . sous la présidence de Mr. Charles Maurain.
8vo. [Coimbra], 1937

Davidson (Rev. M.) :

- The Heavens and Faith. With a Foreword by Sir Frank W. Dyson.
8vo. London, 1936

Davison (Charles) :

- *The distribution of deep-focus earthquakes. 8vo. London, 1937

Douglass (A. E.) :

- Climatic Cycles and Tree Growth. Vol. III.
(*Carnegie Institution of Washington.*) 8vo. Washington, 1936
Vol. III. A Study of Cycles.

Dufay (J.) et Mlle M. Bloch :

- *Etude préliminaire du spectre de Nova Herculis 1934.
(*Lyons Observatory.*) 8vo. Paris, 1936

Dyson (Sir Frank) and R. v. d. R. Woolley :

- Eclipses of the Sun and Moon. [International Series of Monographs on Physics. General Editors: R. H. Fowler and P. Kapitza.]
8vo. Oxford, 1937

Eddington (Sir Arthur):

- : Relativity Theory of Protons and Electrons. cr. 8vo. Cambridge, 1936
 —: Eclipses of the Sun. (In *The Listener*, Vol. XVII, No. 442.)
 (Editor of "*The Listener*.") fol. London, 1937

Euler (Leonhard):

- †Opera omnia; sub auspiciis Societatis Scientiarum Naturalium Helveticae
 edenda curaverunt A. Speiser, L. G. du Pasquier, H. Brandt. Series I.
 Opera Mathematica. Vol. 22. 4to. Basileæ, 1936
 Vol. 22. Commentationes analyticae ad theoriâ æquationum differentialium
 pertinentes, edidit Henri Dulac. Volumen Prius.

Fischer (F.):

- *The lunar formation Šafařík. 8vo. Praha, 1937

Geneva, Observatoire:

- Le service chronométrique en 1935 et 1936. 8vo. s.l., 1937

Gifford (A. C.):

- *In Starry Skies. Part XIV. 8vo. Wellington, 1937
 Part XIV. Our Galaxy and Myriads more.

Gould (R. T.):

- The Man who discovered the Longitude, 1736. John Harrison and his
 Timekeepers. (In *The Listener*, Vol. XVI, No. 416, 1936 December 30.)
 (The Editor of "*The Listener*.") 4to. London, 1936

Gratton (L.) ed E. Krüger:

- *Ricerche sulla distribuzione delle grandezze assolute delle stelle della classe
 spettrale G. 8vo. Roma, 1936

Haffner (H.) und O. Heckmann:

- *Feinstruktur im Farben-Helligkeits-Diagramm des Sternhaufens Praesepe.
 8vo. Berlin, 1936

Halley Lectures:

- †Five Halley Lectures. 8vo. Oxford, 1936
 1930. A. S. Eddington, The Rotation of the Galaxy.
 1932. E. A. Milne, The White Dwarf Stars.
 1933. Henry Norris Russell, The Composition of the Stars.
 1934. Edwin Hubble, Red-Shifts in the Spectra of Nebulae.
 1935. J. S. Plaskett, The Dimensions and Structure of the Galaxy.

Hamburger Sternwarte in Bergedorf:

- Bergedorfer Eigenbewegungs-Lexikon . . . Zweite Ausgabe. Bd. I, II.
 4to. Bergedorf, 1936
 Band I. Nördlicher Sternhimmel.
 Band II. Südlicher Sternhimmel.

Harvard College, Cambridge Branch of the Astronomical Society:

- Full transcript of records, kept by Joseph Winlock, recording secretary, of
 the meetings of the Cambridge Branch of the Astronomical Society 1854-57.
 [Original record in the library of the Harvard College Observatory.]
 (H. Shapley.) 4to. typescript, 1936

Hellweg (J. F.) :

*The United States Naval Observatory.
(*U.S. Naval Observatory.*)

8vo. Annapolis, 1936

Helsingfors, Baltic Geodetic Commission :

Sonderveröffentlichung. No. 6.

8vo. Helsinki, 1937

No. 6. Relative Bestimmungen der Schwerkraft auf den Landeszentralen. Ausgeführt von der Baltischen Geodätischen Kommission in den Jahren 1930 und 1935.

Hinks (Arthur R.) :

Astronomy. Second edition. Revised and largely rewritten.

Demy 8vo. London, 1936

Hiscock (W. G.) :

†David Gregory, Isaac Newton and their Circle. Extracts from David Gregory's Memoranda, 1677-1708. Edited by W. G. Hiscock, Assistant Librarian of Christ Church.

4to. Oxford, 1937

Hogg (A. R.) :

*The mobility of the small ions of the atmosphere.

8vo. Leipzig, 1936

Hubble (Edwin) :

The Realm of the Nebulæ.

8vo. Oxford, 1936

Humberd (Charles D.) :

*Tycho Brahe's Island.

8vo. Northfield (Minn.), 1937

Hyderabad, Nizamiah Observatory :

Astrographic Catalogue 1900-0. Vol. VIII, Part 1.

4to. Edinburgh, 1936

Vol. VIII, Part 1. Comparison of places of stars in the "Catalogue de 9997 Etoiles," Algiers, with the photographic measures on the plates of the Hyderabad Section of the Astrographic Catalogue. Under the direction of T. P. Bhaskaran.

International Astronomical Union :

——: Bulletin for Character Figures of Solar Phenomena. Published by the Eidgenössische Sternwarte in Zürich. Vol. IV, Nos. 34-37.

4to. Zürich, 1937

——: Les Observatoires Astronomiques et les Astronomes. Supplément, par P. Stroobant, E. Delporte, J. Delvosal et F. Moreau, et H. L. Vanderlinden.

8vo. Gembloux, 1936

International Geodetic and Geophysical Union :

——: Association de Géodésie. Bibliographie géodésique internationale. Tome I.

4to. Paris, 1935

Tome I. Georges Perrier et Pierre Tardi, Introduction et années 1928-1929-1930.

——: Association d'océanographie physique. Procès-verbaux. No. 2.

8vo. Edinburgh, 1937

No. 2. General Assembly at Edinburgh, 1936 September.

International Geodetic and Geophysical Union :

—: Association d'océanographie physique. Publication scientifique. Nos. 3, 4.
8vo. Helsingfors, 1936-37

No. 3. Bibliography on Tides and certain kindred matters. Fourth instalment.

No. 4. Phil E. Church, Temperatures of the Western North Atlantic from Thermograph Records.

Interpolation and Allied Tables :

See London, H.M. Nautical Almanac Office.

Iowa, University Observatory :

*Contributions. No. 7.

8vo. Iowa, 1937

Ivanov (A. A.) :

*La plus probable orbite de la Planète (122) Gerda d'après les observations de 1872 à 1934.

8vo. Leningrad, 1937

Järnefelt (Gustaf) :

*Untersuchungen über den Spektrographen der Sternwarte Helsingfors.

8vo. Helsinki, 1936

Jeffreys (Harold) :

—: The Problem of Oceanic Structure. (Communicated to the International Union of Geodesy and Geophysics, Edinburgh Meeting, 1936.)

8vo. Cambridge, 1936

—: Scientific Inference.

8vo. Cambridge, 1937

—: Table for the near earthquake pulses.

8vo. Newport, I.o.W., 1937

(*Oxford University Observatory.*)

Johnson (M. C.) :

*Manuscripts of the Bagdad Astronomers, A.D. 760-1000.

8vo. London, 1936

Kimura (Hisashi) :

*Results of the Values of One Revolution of the Micrometer for the Two South Stations and Batavia deduced from the Observations of the International Scale-Pairs made in those Stations and some North Stations during the Year 1935.

4to. Tokyo, 1936

Klüber (H. von) :

*Ergänzende Sternabzählungen im Dunkelnebel des Taurus.

8vo. Berlin, 1937

Kohlschütter (E.) :

Messkarte zur Auflösung sphärischer Dreiecke. Dritte Auflage.

(*Publishers.*)

Berlin, 1936

Kyoto Imperial University, Kwasan Observatory :

—: Publications. Vol. I, Nos. 3, 4.

8vo. Kyoto, 1931-36

Vol. I, No. 3. Zodiacal Charts (type A) for the use of the Observers of Zodiacal Lights, Gegenscheins and Allied Phenomena. Prepared by the Computing Division, Kwasan Observatory.

Vol. I, No. 4. A. S. Yamamoto, Preliminary General Catalogue of Comets.

—: Bulletin. Nos. 321-326.

4to. Kyoto, 1936

Kyoto, Oriental Astronomical Association :

Oriental Astronomical Bulletin. An international Magazine of Astronomy and the Related Sciences from the Orient. [Continuation of Kwasan Observatory Bulletin.] Vol. 4, No. 327. 4to. Kyoto, 1937

Labitzke (P.) :

*Bestimmung des Einflusses deformierten Achsenzapfen auf die Beobachtungen mit einem Passageninstrument. cr. 8vo. Berlin, 1934

Lisbon, Academia das Ciências :

Biblioteca de altos estudos. Théorie générale de la co-ordination moléculaire, por G. Urbain. sm. 8vo. Lisboa, 1935

London, H.M. Nautical Almanac Office :

*Interpolation and allied tables. 8vo. London, 1936

London, The Physical Society :

Reports on Progress in Physics. Vol. III. 8vo. London, 1937

London, Royal Astronomical Society :

*George Darwin Lectures, 1936, 1937. (Tenth and eleventh lectures.) 8vo. London, 1936-37

1936. A. Kopff, Star Catalogues, especially those of fundamental character.

1937. N. E. Nörlund, Astronomical longitude and azimuth determinations.

London, Royal College of Science Association :

Register of Old Students and Staff of the Royal College of Science which, together with the Royal School of Mines and the City and Guilds College, now constitutes the Imperial College of Science and Technology, a School of the University of London. Fifth edition. 8vo. London, 1936

London, Royal Geographical Society :

†Hints to Travellers. Eleventh Edition. Vol. I. 8vo. London, 1935

Vol. I. E. A. Reeves, Survey and Field Astronomy. With some additions and revision by other hands.

London University :

Centenary Commemorative Volume. 1836-1936. 1936 June 27-July 3. 8vo. London, 1937

McIntosh (R. A.) :

*Report of the Section (N.Z. Astron. Soc.) for the observation of Meteors, 1932-34. 8vo. Dunedin (N.Z.), 1936

Martin (Willem Christiaan) :

Photographische photometrie van veranderlijke sterren in ω Centauri. 8vo. Leiden, 1937

Martyn (D. F.) and A. L. Green :

*The characteristics of downcoming radio waves. 8vo. London, 1935

Mauritius, Royal Alfred Observatory :

—: Miscellaneous Publications. No. 16. fol. Port Louis, 1936
 No. 16. N. R. McCurdy, The Cyclone Season 1933-34 at Mauritius.

—: Publications. No. 18.

8vo. Port Louis, 1937

No. 18. M. Herchenroder, The atmospheric pressure at Mauritius: being a survey and discussion of fifty-six years' observations made at the Royal Alfred Observatory. Lat. 20° 1 S., Long. 57° S.E. (55 metres above M.S.L.).

Mees (C. E. Kenneth) :

Photography.

8vo. London, 1936

Mémery (Henri) :

Les bases de l'influence des phénomènes solaires en météorologie.

8vo. Talence, 1936

Menzel (Donald H.) and Joseph C. Boyce :

*Eclipse in Ak Bulak.

4to. Cambridge (Mass.), 1936

(*Harvard Observatory.*)

Merate, R. Osservatorio Astronomico :

Pubblicazioni. No. 8, Parte I, II.

4to. Milano, 1935-36

Meyer (G.) :

—: *Occultations d'étoiles par la lune observées à Bordeaux en 1933.

4to. Marseille, 1935

—: *Occultations d'étoiles par la lune observées à Bordeaux en 1934.

4to. Bordeaux, *s.d.*

— et H. Godard :

—: *Positions photographiques d'étoiles.

(*The above three articles bound in one cover.*)

4to. Marseille, 1936

Meyer-Bührer (Hch.) :

Zum Zodiallicht-Problem. (Denkschriften der Schweizerischen Naturforschenden Gesellschaft. Band LXXI, Abh. 4.)

(*The Royal Society of London.*)

4to. Zürich, 1936

Minneapolis, University of Minnesota, Astronomical Observatory :

Publications. Vol. II, No. 4.

8vo. Minneapolis, 1936

Vol. II, No. 4. Willem J. Luyten, A Re-discussion of the Orbits of seventy-seven Spectroscopic Binaries.

Moscow University, Sternberg Astronomical Institute :

Central Bureau for Variable Star Investigation in U.S.S.R. Plan of investigation of unstudied variable stars. With map.

16mo. Moscow, 1936

Newton (Isaac) :

See **Hiscock (W. G.)**, and **Stukeley (William)**.

Newtonian Society :

Occasional Papers. No. 1. 1937 April.

8vo. St Albans, 1937

Nijland (A. A.) :

- *Mittlere Lichtkurven von langperiodischen Veränderlichen. I, V, VI, VII, VIII, IX, X, XXVIII, XXIX, XXX. 8vo. Amsterdam, 1930-37
(*Utrecht Observatory*.)

I. W Herculis.	IX. γ Cygni.
V. S Ursæ majoris.	X. T Ursæ majoris.
VI. R Cygni.	XXVIII. Z Ceti.
VII. S Bootis.	XXIX. U Persei.
VIII. R Leonis minoris.	XXX. S Lyncis.

Optical Society of America :

- †Journal . . . and Review of Scientific Instruments. Vols. I-XV.
8vo. Rochester, Philadelphia, Menasha, 1917-27

Orr (M. A.) :

- †Dante and the Early Astronomers. 8vo. London, 1913

Oxford, University Observatory :

- *Communications. Nos. 8, 9. 8vo. Oxford, 1936-37

Paris, Observatoire :

- Tables de précession pour des changements d'équinoxe de 25 et de 50 ans
et pour tout autre changement d'équinoxe.
8vo. Orléans, 1935

Parvulesco (Constantin) :

- : *La Voie-Lactée est un phénomène local, incompatible avec l'hypothèse
super-galactique. 8vo. Cernauti, 1935
——: *Sur l'unification des cartes de distributions galactiques et sur le meilleur
système de projection à adopter. 8vo. Cernauti, 1935

Peisino (G.) :

- *Osservazioni dell'eclisse solare del 19 giugno 1936 eseguite visualmente e
fotograficamente nel R. Osservatorio Astronomico di Trieste.
8vo. Pavia, 1936

Phillips (E. William) :

- *Binary Calculation. 8vo. Cambridge, 1936
(*L. J. Comrie*.)

Pirot (Admiral G. O.) :

- Détermination et étude du temps Newtonien par les occultations d'étoiles.
4to. Orléans, 1937

Poggendorff (J. C.) :

- †Biographisch-literarisches Handwörterbuch. Band VI: 1923 bis 1931.
II Teil, F-K. 8vo. Berlin, 1937

Poincaré (H.) :

- †Figures d'équilibre d'une masse fluide. Leçons professées à la Sorbonne
en 1900. 8vo. Paris, 1902

Polar Year, British National Committee for :

British Polar Year Expedition, Fort Rae, N.W. Canada, 1932-33. Vols. I, II.
(*Air Ministry.*) 4to. London, 1937

Vol. I. Discussion of Results.

Meteorology, Terrestrial Magnetism and Aurora, Atmospheric Electricity.

Vol. II. Tables.

Meteorology, Terrestrial Magnetism, Atmospheric Electricity.

Posen, Observatoire Astronomique de l'Université :

—: Poznań Reprint. Nos. 1-4. 4to. Poznań, 1936

—: *Rapport sur les travaux et l'état de l'Observatoire Astronomique de
l'Université de Poznań, 1931-1936, par J. Witkowski.

(*J. Witkowski.*) 8vo. Poznań, 1936

Proctor (Mary) and A. C. D. Crommelin :

Comets, their nature, origin, and place in the science of astronomy.

(*Publishers.*) 8vo. London, 1937

Rannie (J. L.) and W. M. Dennis :

*Axis strain in theodolites, its effects, and one method of removal.

(*Canada, Minister of the Interior.*) 8vo. Ottawa, 1936

Reed's Nautical Almanac and Tide Tables :

1937. Editor: Captain O. M. Watts, A.I.N.A. 8vo. Sunderland, 1937

Research and Progress :

Quarterly Review of German Science. Vol. III, No. 2. 1937 March-April.

8vo. Berlin, 1937

Riverview College Observatory :

—: Publications. Nos. 2, 3.

4to. Sydney, 1936

—: Reprint. No. 1.

8vo. Sydney, 1936

Rome, Reale Accademia Nazionale dei Lincei :

Indice degli Atti Accademici pubblicati dal 1925 al 1934.

8vo. Roma, 1936

Rome, R. Osservatorio Astronomico sul Campidoglio :

—: *Contributi Scientifici (Nuova Serie). Nos. 56-60.

8vo. Roma, 1936

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MONTHLY NOTICES
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ANNOUNCEMENT OF PAPERS RECEIVED

Post-cards, giving the titles of such Papers as have been received up to the Saturday preceding the day of the Ordinary Meeting, will be sent to those Fellows who inform the Assistant Secretary of their wish to receive them.

NOTICE TO AUTHORS

1. Authors are notified that Papers should be received by one of the Secretaries or by the Assistant Secretary not later than the Saturday previous to each Meeting. Papers received later will be held over.

2. Authors are requested to send their manuscripts in as convenient a form for publication as possible. MSS. must be clearly written or type-written; otherwise they may be returned to the senders to be recast. Tabular matter should be arranged so that it can be printed upright on the page, and the number of columns and the number of figures in each column should be carefully considered from this point of view.

3. Authors should conform as closely as possible to the recommendations of the I.A.U., especially those of Commission 5 on Bibliography (*Trans. I.A.U.*, vol. 3, 1928). In particular, the date (year of publication) of *every* publication referred to, in footnotes or elsewhere, should be given. The abbreviation U.T. should be used to denote Mean Time commencing at Greenwich midnight.

4. The unit of wave-length should be written "angstrom" (small a, no accents), *not* "Angstrom Unit." The abbreviated form should be simply "A." (*e.g.* 6563 A.). In spectral classification the decimal divisions should not be written as suffixes, *e.g.* write F₅ and *not* F₅.

5. Diagrams or other illustrations accompanying Papers should be sent in a state suitable for direct photographic reproduction. It is preferable that diagrams should be drawn on a larger scale than required, in Indian ink on white paper, all lines, etc., being sufficiently bold to bear the reduction required. Any lettering should be written in pencil, that it may be re-drawn to the proper scale.

6. The attention of authors is particularly directed to the rule of the Council that when the cost of alterations to proofs exceeds 5 per cent. of the cost of setting up the type of a Paper, the excess must be borne by the author.

7. The Council has decided to destroy all MSS. of Papers presented to the Society which remain in their possession after the expiration of twelve months from the dates of publication. Authors who desire to recover their MSS. after that interval may do so if previous notice is given.

8. *Epidiascope*.—Readers of papers are requested to note that diagrams, tabular matter, etc. to be exhibited on the screen with the epidiascope should not exceed six inches square.

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